INSTRUCTOR'S MANUAL
CHARLES KAZILEK ◦ KIM COOPER

MARTINI

FUNDAMENTALS OF

Anatomy & Physiology

FIFTH EDITION

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INSTRUCTOR'S MANUAL

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MARTINI

FUNDAMENTALS OF Anatomy & Physiology

FIFTH EDITION

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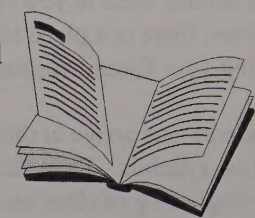
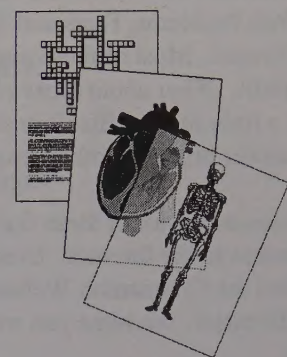
Chapter-by-Chapter Materials: Chapters 1-29

PLEASE TEAR APART THIS INSTRUCTOR'S MANUAL!
(formerly the Preface)

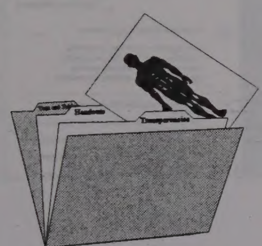


It's true: we advocate tearing this book apart. Certainly don't leave it in its traditional form or you may not get the full benefit of the material. This **Instructor's Resource Package** has been created with ease of lecture preparation in mind. The first step is this **Instructor's Manual*** with its pages that tear out easily to be reorganized any way you like.

*Chapter-by-chapter, the **Instructor's Resource Package** gives you....*

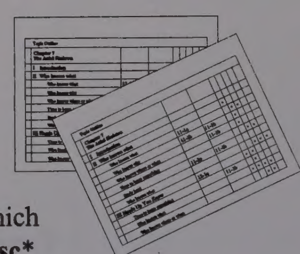


- <u>Teaching Strategies</u>--featuring valuable demonstration ideas, useful analogies, new information on how to overcome Common Student Misconceptions and Media Lab Instructor Notes (all found in the Instructor's Manual).
- <u>Student Handouts</u>--including vocabulary-building Crossword Puzzles and answers to *Fundamentals'* end-of-chapter questions are included in the Instructor's Resource Package. All the handouts are printed so they may be easily copied and distributed to students. **Quiz Art*** lets you test students easily on the figures they've studied in class.
- <u>Transparency Acetates*</u>--over 95% of the images in *Fundamentals* on 800 acetates.



We suggest a separate folder for each chapter or lecture topic. Then use dividers to create sections for relevant handouts and transparencies. Add your own class notes to a particular folder and you are ready to head off to class!

***Chapter Outline and Audio/Visual Grids** help you optimize your preparation time by.....*



Outlining each chapter, indicating relevant teaching strategies, and showing which audio-visual aids are available for each topic. Found in the Instructor's Manual, these grids tell you, at a glance, which text figures go with each topic, which topics have a related still image or animation on the **CD-ROM*** or **A&P Laserdisc***, and which topics have relevant **Video Tutor** discussions. Great to use as lecture outline in class or to organize your AV materials as you prepare beforehand!

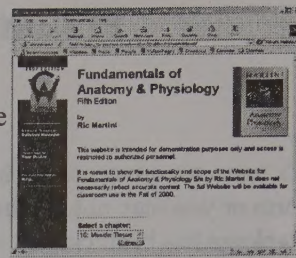
*Try the Martini **Companion Website*** that offers you and your students more resources.....*

To some, the Internet may appear as an interesting but intimidating media. For others with experience in web development, it is clear that building web sites takes a large amount of time beyond preparing for class lectures, quizzes and exams. To help make life easier in this brave new world, Prentice Hall has developed a web tool for you and your students. Best of all, no web media experience is required. In fact, you do not need to have any web server technology at your institution to make use of the Companion Website. All that is required is an E-mail account. The Companion Website for 2000 will meet many of your needs as well as add some impressive web activities. For those of you that teach the same class at different schools, the Companion Website is a way to save time and simplify your life.

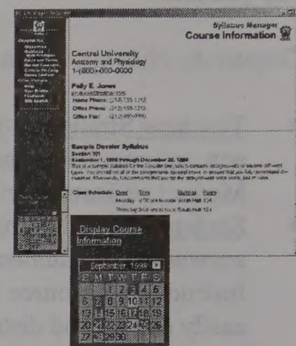
Prentice Hall 2000

You begin by setting up your class syllabus and calendar at the Companion Website. The usual meeting information, office hours, and grading criteria. Next you can enter the

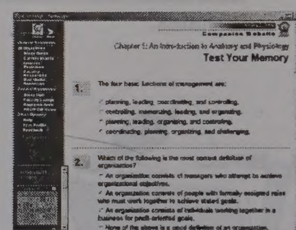
daily assignments, including any additional on-line quizzes, review concepts and critical thinking modules that will be required. Not to worry, all these modules have been created. You just assign the material and the students take the quizzes and submit them to you via E-mail for a grade. For those of you that have very large classes, there is a place to enter a TA's name and E-mail address so you can avoid filling your E-mail account with hundreds of student submissions.



Students that arrive at the site enter your name or E-mail account to access your online syllabus. To make the experience easier, the student can fill out a profile at the beginning of class session and it will keep all the needed information for submission. When they submit homework, they do not have to reenter their information. The online chapter materials include, Chapter Objectives, MediaLab: Web Problems, Facts and Terms, Review Concepts, Critical Thinking and Ebook Content. Most of these materials can be submitted for a homework grade or extra credit. *What about those clever students that like to share their answers?* To make it a little more difficult to share answers, many of the modules randomize the answer order. In other cases, the questions require a written answer.



Remember, all of these features are possible with only an E-mail account and access to the Internet. Even if you are not a web wizard you and your students will find the Companion Website loaded with tools and teaching materials to make your life easier. We hope you will try out this great resource. We are sure you will like it.



Charles Kazilek
Kim Cooper

Your complete Instructor's Resource Package includes:

* 800 transparency acetates
* Quiz Art pack (includes 200 unlabeled key text figures)
* CD-ROM image disk
  (animations and still with and without labels)
* Laserdisc image platter
* Companion Website
  (http://www.prenhall.com/martini/)

Sorry For The Headaches

(Formerly the Acknowledgments)

We would like to thank the following people for either putting up with some headaches or not causing too many.

Don O'Neal, Karen Karlin, Andrew Stull, Kate Flickinger

CHAPTER 1

An Introduction to Anatomy and Physiology

❑ Introduction

Homeostasis is the central unifying concept in physiology. Homeostasis works by feedback loops. These two concepts are rather abstract and can be difficult for students to grasp. The following activity might help make these concepts more concrete. First, emphasize that we are made of cells and cells are the simplest form of life. Most students will already be familiar with this concept. Break the students into groups, each group will be acting as a consulting firm. Tell the students that their firms are being hired to help design a system to keep human cells alive outside the body. Each firm is to produce a part of the overall plan. Before they begin, ask the groups in what kind environment they will keep the cells. Your goal is to point out that the cells must be kept in a water-based environment. Ask the students if the water solution has to have any special properties. They should easily come up with the idea that the temperature, oxygen and nutrient levels must be fairly constant. Go to the board and produce a list of the aspects of the cell surroundings that must be kept relatively constant. You could add other things to the list like pH, osmolarity, etc. Let each group choose one aspect (such as temperature) and design a system to control it. When they're done, review the plans. Now it should be easy to introduce the concept of homeostasis (the need to keep the environment around cells constant). The students will essentially have discovered the idea of a negative feedback loop to maintain homeostasis. Emphasize that the key components of a feedback loop are a sensor, an integrator and effectors.

❑ Instructional Goals/Learning Objectives

1. To familiarize students with the **organizational scheme** and **standard terminology** of the body.

   a. Describe the basic functions of living organisms.
   b. Identify the major levels of organization in living organisms, from the simplest to the most complex.
   c. Identify the organ systems of the human body and the major components of each system.
   d. Use anatomical terms to describe body sections, body regions, and relative positions.
   e. Identify the major body cavities and their subdivisions.

2. To introduce fundamental concepts, including the **complementarity of structure and function**, and **homeostatic regulation** of organ systems.

   a. Define anatomy and physiology, and describe various specialties of each discipline.
   b. Explain the concept of homeostasis, and its significance for living organisms.
   c. Describe how positive and negative feedback are involved in homeostatic regulation.

❑ Teaching Strategies

1. Analogies

a. As an analogy for homeostasis, imagine a circus performer perched on a board that is resting on a ball. As the performer balances, he never holds perfectly still; his out-stretched arms are continuously moving up and down, his weight is continuously shifting from one leg to the other. As long as he moves his arms and weight within a limited, physical range, he can maintain his balance on the ball; but as soon as his left arm goes up too high or his weight shifts too far to the right, he loses his balance and falls to the ground. Keeping ourselves from falling off the ball is the basis for homeostatic regulation. The absence of homeostasis is called disease.

b. The analogy of the thermostatic control of room temperature used in the text is an excellent illustration of the component parts or pathway involved in homeostatic regulation. Draw the pathway on the board:

thermometer	➜	rheostat	➜	air conditioner
receptor	➜	control center	➜	effector

Emphasize that there must be an original stimulus (a change in the environment) and that the pathway is ONE-WAY; the receptor can only receive information about the environment, it cannot respond. The effector can only respond if the control center sends a message to do so. Of course, the crucial link between the effector and the receptor is feedback. Since this is the same pathway that is modeled in the nervous system and in a reflex arc, it is appropriate to introduce the terminology afferent (toward the center) and efferent (away from the center) at this time.

2. Vocabulary Aids

a. Discussion of the concept of metabolism offers an opportunity to introduce the terms catabolism and anabolism. Thus, an organism's metabolic processes are a sum total of all the chemical reactions that start with larger molecules and break them down to smaller units plus those that start with smaller molecules and build them up to larger units. Demonstrate the alliteration between CUT or CUT APART and CATabolism, and ADD or ADD ON and ANAbolism.

b. Encourage the students to find the anatomical landmarks and regions ON THEIR OWN BODIES while they study the terms in the text. Anatomical directions are more easily mastered if they are studied in pairs of antonyms. Emphasize that the terms are relative to each other.

c. Emphasize that to designate a specific membrane of the body requires two adjectives: one that determines whether it is visceral or parietal and a second that defines the cavity. The word parietal sounds like the word perimeter which means the outer boundary, just as the walls of a cavity define its outer boundary.

3. Common Student Misconceptions/Problems

a. One of the most difficult concepts for students to understand is that homeostasis is a completely dynamic process, one that is constantly fluctuating between normal limits. In spite of the literal meaning of homeostasis, we never are physiologically in a state of "unchanging sameness" unless we're dead! (For this reason, it is important that students be aware of ranges of normalcy when learning physiological parameters like pH of blood, RBC count, or cardiac rate).

b. The mediastinum is not a cavity, but rather a region within the thoracic cavity. The mediastinum contains the pericardial cavity.

4. Lecture ideas

a. Stress the relationship between anatomy (structure) and physiology (function). As described in the text: "All specific functions are performed by specific structures" (and vice versa). If a structure changes, even if the change is at a molecular level, it will no longer perform its original function. The structure/function relationship will become an important way of predicting one given the other. For example, if the function of a mitochondrion is to act as a principle site of ATP synthesis for cellular energy, and in the structure of a liver cell, there are large numbers of mitochondria, then it can be deduced that its function must require a great deal of energy.

You are entering a bicycle race, and you must choose between two bikes: a sleek racing bike, weighing only 3.5 lbs, with razor-sharp wheels to reduce road friction, and a slick, new aero-dynamic design guaranteed to eliminate excess air resistance OR a heavy-duty bike, weighing 20 lbs, with thick, deeptread tires that grab the road, and a solid titanium frame, guaranteed to handle any stress. Which bike do you choose? Why? What do you need to know before making a decision? What if the race is in the Colorado mountains? Both vehicles are unmistakably bicycles, but the specific structure of each allows them to perform a specific function.

b. Sectional anatomy is exceedingly difficult for students to visualize. Have them do several drawing exercises to reinforce the visualization process. Elaborate on Figure 1-12 in the text. Use examples of common items such as a donut or shapes of pasta and encourage the students to draw the image that would result from various planes of sections. Point out the usefulness of describing planes of section in terms of the two parts that are produced: a sagittal section produces a right and a left piece; a transverse section produces a superior and an inferior piece; a frontal section produces an anterior and a posterior piece.

c. Body cavities are lined with serosal membranes that secrete serosal fluid. The rest of the body, such as the limbs, are "solid" tissue, containing no cavities. Take time to draw an example on the board, such as the heart in the pericardial cavity. Label and describe the difference between the parietal and visceral membranes. Illustrate that the parietal membrane is on the wall, while the visceral membrane touches the surface of the organ, and the cavity is the space between the membranes.

❑ Answers to End of Chapter Exercises

Level 1: Reviewing Facts and Terms

1.	g	12.	o	23.	c
2.	d	13.	k	24.	a
3.	a	14.	i	25.	d
4.	j	15.	m	26.	c
5.	b	16.	c	27.	d
6.	l	17.	b	28.	b
7.	n	18.	b	29.	c
8.	f	19.	a	30.	c
9.	h	20.	d	31.	b
10.	e	21.	a		
11.	c	22.	b		

Level 2: Reviewing Concepts

32. Responsiveness, adaptability, growth, differentiation, reproduction, movement, metabolism, absorption, respiration, excretion.

33. (a) Anatomy is the study of internal and external structures and the physical relationships among body parts. (b) Physiology is the study of how living organisms perform their vital functions.

34. The organization at each level determines the characteristics and functions of higher levels.

35. chemical (atoms and molecules)-cellular-tissue-organ-organ system-organism.

36. Homeostatic regulation refers to adjustments in physiological systems that are responsible for the preservation of homeostasis.

37. Autoregulation occurs when the activities of a cell, tissue, organ or system change automatically (i.e. without neural or endocrine input) when faced with some environmental variation. Extrinsic regulation results from the activities of the nervous or endocrine systems. It causes more extensive and potentially more effective adjustments in activities.

38. Receptor -receives the stimulus; control or integration center -determines if stimulus has upset homeostasis, and initiates an appropriate response; effector -responds to the stimulus according to instructions from the control center.

39. In negative feedback, a variation outside of normal range triggers an automatic response that corrects the situation. In positive feedback, the initial stimulus produces a response that exaggerates the stimulus.

40. The body is erect and the hands are at the sides with the palms facing forward.

41. Serous membranes surround the organs. They secrete a watery fluid that reduces friction when the organs move within the internal cavities.

42. Stomach. (You'd cut the pericardium to access the heart.)

43. (a) Dorsal cavity (b) Ventral cavity (c) Thoracic cavity (d) Abdominopelvic cavity

44. (a) Pericardium (b) Pleura (c) Peritoneum

Level 3: Critical Thinking/Clinical Application

45. Since calcitonin is released when calcium levels are elevated, it should bring about a decrease in blood calcium level, thus decreasing the stimulus for its release.

46. The initial increase in blood flow to active muscles is an example of autoregulation. The increased demands for oxygen and waste removal cause a local increase in blood flow even before responses from the nervous or endocrine systems take place. The change involved is autoregulation, because it is an immediate and automatic response to environmental change (low oxygen and increased wastes), that does not require the nervous or endocrine systems.

47. b

❑ Media Lab Instructor Notes

Web addresses often change. To avoid dead links, we are listing the keywords in parentheses next the to Web Explorations. Simply go to the Companion Website (http://www.prenhall.com/martini), then select the Fifth Edition of Fundamentals of Anatomy and Physiology and search using the key word to locate the current address.

Animations (Website)
- Figure 1-2—Animation in overlay format. Organ systems—suitable for self-study or to quickly introduce the organ systems during lecture.
- Figure 1-4—Animation in play/pause format. Negative feedback in body temperature control. Suitable for lecture enhancement during negative feedback explanation.
- Figure 1-6—Animation with pop-up labels. Anatomical Landmarks—suitable for self-study.

Web Explorations (Overview)
Web Exploration 1 **(TERMINOLOGY)**

- *Goal*—study skills enhancement, beginning vocabulary list, cooperative learning
- *Description of page*—patient's guide to medical terminology with side bar links to other patient resources
- *Expectations of student behavior*—read introductory page, click to linked pages, find and copy down meanings of words used in class
- *Instructor's role*—highlight medical terms in lectures to direct students as they approach this page
- *Special notes or further uses of exploration*—bookmark site for continued reference.

<u>Web Exploration 2</u> (**PLANES**)

- *Goal*—visualization techniques, spatial learning
- *Description of page*—visible human sections complied by Washington University School of Medicine
- *Expectations of student behavior*—read information, click and watch animations, potential frustration when first attempting to visualize organs
- *Instructor's role*—introduce section types, visible human project, reference as students interpret images
- *Special notes or further uses of exploration*—links back to MAD scientist homepage at WUSM worth investigating; be aware students can follow links far from originating page.

Additional Web Explorations
Should the two explorations found in the text not answer your needs, a third exploration is provided below. Your students do not have direct access to this exploration. You must provide them the address and information in the following paragraph.

<u>Web Exploration 3</u>
Estimated time for completion = 10 minutes

Ion homeostasis is maintained via negative feedback mechanisms. Blood calcium levels must be maintained within normal ranges for such functions as muscle contraction and nerve impulse transmission. The exact mechanism for maintaining blood calcium levels is currently being researched. Go to this Website (http://www.med.harvard.edu/publications/Focus/complete_texts/Oct20_1995_complete.html) and read the article entitled "Maintaining an ionic calm." Draw a diagram similar to figure 1-4 from your text depicting the current understanding of the homeostatic control of calcium in the body.

<u>Web Exploration 3</u> (**HOMEOSTASIS**)

- *Goal*—critical thinking, information synthesis (calcium cycling)
- *Description of page*—Focus journal entire issue (not overly scientific, but not Popular Science)
- *Expectations of student behavior*—read information and diagram calcium control mechanisms
- *Instructor's role*—explanation of terminology in article, discussion of scientific articles, assistance in interpretation of data
- *Special notes or further uses of exploration*—this is a good resource for future information. The issue here also includes an ethics article worth noting.

Topic Outline				A/V Resources				
Objectives	**Chapter 1** **An Introduction to Anatomy and Physiology** (page 1 of 2)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
1a	**I. Introduction**		2a					
2a	**II. The Sciences of Anatomy and Physiology**		4a					
	A. Anatomy							
	1. Microscopic Anatomy							
	2. Gross Anatomy							
	B. Physiology							
1b	**III. Levels of Organization**	1-1,2		●	●	●		
2b	**IV. Homeostasis and System Integration**	1-3	1a,b	●	●			
	A. Negative Feedback	1-4ab	3a	●	●	●		
	B. Positive Feedback	1-5		●	●			
1d	**V. A Frame of Reference for Anatomical Studies**							
	1. Anatomical Landmarks	1-6		●	●	●		
	2. Anatomical Regions	1-6,7bc		●	●			
	3. Anatomical Directions	1-8	2b,4b	●	●			●

Topic Outline				A/V Resources				
Objectives	**Chapter 1** **An Introduction to Anatomy and Physiology** (page 2 of 2)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	B. Sectional Anatomy		4b					
	1. Planes and Sections	1-9		●	●			●
1e	2. Body Cavities	1-10, 11	2c,3b,4c	●	●			●

CHAPTER 2

The Chemical Level of Organization

Introduction

We tend to think of the chemical level of organization as the smallest relevant to anatomy and physiology. While this is true, the single biggest science project at the moment involves the study of twenty-three molecules from a human. The total budget for this project is three billion dollars and it is expected to take 15 years to complete. The Human Genome project has as its goal the conceptually simple task of determining the exact nucleotide sequence of the chromosomes of a human being. Hidden within the structure of these molecules is the recipe to make a person. The basis of many diseases will be uncovered during the process. Analogous projects are also sequencing the chromosomes of other organisms. Several have already been completed. What more evidence could one ask for to show that the chemical level of organization is important and fundamental?

Instructional Goals/Learning Objectives

1. To provide the **basic background** in chemistry and **chemical notation** needed in later chapters.

   a. *Describe an atom and how atomic structure affects interactions between atoms.*
   b. *Compare the different ways in which atoms combine to form molecules and compounds.*

2. To introduce the **major chemical constituents of the body**.

   a. *Distinguish between organic and inorganic compounds.*
   b. *Describe the physiological roles of inorganic compounds.*
   c. *Explain how the chemical properties of water make life possible.*
   d. *Discuss the importance of pH and the role of buffers in body fluids.*
   e. *Discuss the structure and functions of carbohydrates, lipids, proteins, nucleic acids, and high-energy compounds.*

3. To introduce the concepts of chemical reactions and the **equilibrium** state.

   a. *Distinguish among the major types of chemical reactions that are important for studying physiology.*
   b. *Describe the crucial role of enzymes in metabolism.*

4. To **alleviate student fears of chemistry**, and to **encourage their interest** in events at the chemical level.

❑ Teaching Strategies

1. Analogies

a. Anthropomorphize molecules by describing them as both "greedy" and "lazy." They are greedy enough to want the outer energy level complete, and they feel agitated until it is complete, so agitated that they will constantly look around for someone else's excess electrons. However, they are too lazy to complete the outer level if it means taking on more than half the number of electrons required to fill the level. In those cases, they would just as soon give up the electrons in the outer energy level. They will be left with one less energy level, but at least it will be complete! A few molecules are lucky enough to come equipped with completed outer energy levels, and so they are happy to just sit and not interact with anyone (inert gases).

Likewise, if atoms can't agree upon who is going to give up an electron to make an ionic bond, they may end up just sharing the electron in their outer shells. If the molecules doing the sharing are the same size, then they share equally (nonpolar bonds), but if one molecule is bigger, because it has a bigger nucleus (and more + charge), then it will "hog" the electrons most of the time (polar bonds). Emphasize that polar covalent bonds are very different from ionic bonds.

b. Compare the primary structure of a protein with a train made up of 20 types of cars (amino acids). The look and function of the train will vary depending upon which of the 20 cars and how many of each of those cars are linked together. A train with an engine, 3 flat beds, 4 box cars, and a caboose will perform a different function than a train with an engine, 5 passenger cars, and a caboose. Note that they both start and end with the same cars. Each car has front and back coupling, so the front coupling of one car must hook to the back coupling of the preceding car (as in a peptide bond).

c. Enzymes will work at their optimum rate as long as there is plenty of substrate, and the temperature and pH are constant. If the manager of a Subway™ shop gets an order for 200 sandwiches, he (the enzyme) will continue to assemble sandwiches down the assembly line of condiments as fast as he can (never getting "used up"), until he runs out of ingredients (substrate). The only way his rate of producing sandwiches (product) can change is if the environment in which he is working changes to the degree that it slows his progress.

d. Compare the entire DNA structure to a spiral staircase: the sugar and phosphate make up the railings and side supports, while the bases are analogous to the steps.

2. Demonstrations

a. Compare the different levels of protein structure with ribbon used to wrap a package. A ribbon can be stretched out straight (primary), coiled in a spiral (secondary), crimped (secondary), or stripped with a scissors so that it develops many overlapping curls (tertiary). You can even bunch several of the curly ribbons together to make one large bow (quaternary).

b. Or compare protein structure to a telephone cord; single wire = primary structure, coiled cord = secondary structure (alpha helix), tangled and coiled = tertiary structure, several tangled cords = quaternary structure.

3. Vocabulary Aids

a. Think of the "t" in cation as a "+" sign to remember that a cation has a positive charge. Since a cation exists as a result of "catapulting" its electrons away, the positive charge is due to its excess protons (both words begin with "p"). An anion *a*dds (both words beginning with "a") electrons, so it is negative (there is also an a in negative).

b. To distinguish hydrophilic from hydrophobic, try this alliteration: You would like to lick a lollipop all the time, but you have a phobia for getting fat.

c. Indicate that purines and pyrimidines are like jigsaw puzzle pieces. Purines are "outies" and pyrimidines are "innies." When pairing bases, one has to match an outie with an innie. Ag (adenine/guanine) is the chemical symbol for silver, you always want pure silver (purine). There are 3 pyrimidines: T, C, U; just like the 3 points to a pyramid.

4. Applications

a. During the discussion of free radicals, mention the current fad to supplement the diet with "antioxidants" like vitamins C and E (although the roles of antioxidants are unclear).

b. Indicate that prostaglandins are part of most cells of the body. and stress how important they will be in future discussions as indicated in the text.

c. Explain the structural and functional roles of cholesterol.

d. Explain the structural and functional roles of phospholipids and glycolipids.

5. Common Student Misconceptions/Problems

a. Each numerical change in a pH unit represents a 10-fold change in the concentration of H^+ ions. The bigger the pH number, the smaller the concentration of H^+ ions (and vice versa). The pH of any solution is relative: an acidic solution like coffee may be considered alkaline as compared to lemon juice. If the blood pH is 7.3, that is an alkaline pH, but it is acidic compared to the normal pH of blood (7.35-7.45). H^+ ions can only affect the pH if they are floating free in a solution. A buffer acts like an ion sponge, holding the H^+ ions, or releasing them as needed.

b. A common mistake students make is confusing the alpha helices in DNA and protein. To help avoid this, emphasize that both protein and DNA have secondary structure and both are called alpha-helix, but the detailed structures differ.

6. Lecture ideas

a. Direct the students to observe the periodic table in the appendix. Using the table as a guide, reiterate the concepts that were introduced in the outline: atomic number, chemical symbol, element, atomic weight. Explain the horizontal and vertical arrangement of the elements, and what gives the table its "periodicity."

b. Even though a single hydrogen bond is relatively weak as compared to ionic and covalent bonds, the sum total of all hydrogen bonds within a single molecule can be quite powerful. They are the basis for the shape of larger, 3-D molecules like proteins, and often times it is the H-bonds that are affected when pH and temperature changes occur.

c. It is very important to illustrate that H-bonds occur between separate molecules (or distant regions of a large molecule), whose atoms are joined by polar covalent bonds. A board drawing of several water molecules, with both the polar covalent and the H-bonds clearly labeled, will emphasize this point.

❑ Answers to End of Chapter Exercises

Level 1: Reviewing Facts and Terms

1.	a	10.	i	19.	l
2.	b	11.	c	20.	b
3.	d	12.	o	21.	c
4.	a	13.	f	22.	d
5.	h	14.	b	23.	a
6.	n	15.	m	24.	b
7.	e	16.	d	25.	d
8.	k	17.	g	26.	a
9.	a	18.	j	27.	b

28. protons, neutrons, electrons

29. Potential energy is stored energy. Kinetic energy is the energy of motion.

30. Enzymes are specialized protein catalysts that lower the activation energy for chemical reactions. Enzymes speed up chemical reactions, but are not used up or changed in the process.

31. Carbon dioxide, oxygen, water, inorganic acids, inorganic bases, inorganic salts.

32. Carbohydrates, lipids, proteins, nucleic acids.

33. (1) provide a significant energy reserve (2) serve as insulation; heat preservation (3) provide cushioning to protect organs.

34. (1) support-structural proteins; (2) movement-contractile proteins; (3) transport-transport proteins; (4) buffering; (5) metabolic regulation; (6) coordination and control-hormones and neurotransmitters; (7) defense (antibodies)

35. (a) DNA-deoxyribose, phosphate, nitrogen containing bases (A,T,C,G); (b) RNA-ribose, phosphate, nitrogen containing bases (A,U,C,G)

36. (1) adenosine (2) phosphate groups (3) appropriate enzymes

Level 2: Reviewing Concepts

37. c
38. c
39. d

40. (a) 20 protons (b) 20 electrons (c) 20 neutrons (d) atomic number = 20 (e) atomic weight-40 (f) 1st level-2 electrons, 2nd level-8 electrons, 3rd level-8 electrons, 4th level-2 electrons

41. (1) covalent bond-equal sharing of electrons (2) polar covalent bond-unequal sharing of electrons (3) ionic bond-loss and/or gain of electrons

42. A great deal of energy must be provided to raise or lower the temperature of a volume of liquid water by 1 degree C. Once a large volume of water has reached a particular temperature, it will change temperature only slowly. Because water accounts for roughly 66 percent of body weight, thermal inertia helps to stabilize body temperature.

43. A solution such as pure water with a pH of 7 is neutral because it contains equal numbers of hydrogen and hydroxyl ions.

44. Buffers maintain pH within normal limits by removing or replacing hydrogen ions as needed.

45. The molecule would be a nucleic acid. Carbohydrates and lipids do not contain the element nitrogen. Although both proteins and nucleic acids contain nitrogen, only nucleic acids contain phosphorus (note: proteins could have phosphorus if they have been phosphorylated for control purposes).

Level 3: Critical Thinking/Clinical Applications

46. The number of neutrons in an atom is equal to the atomic weight minus the atomic number. In the case of sulfur, this would be 32 - 16 = 16 neutrons. Since the atomic number of sulfur is 16, the neutral sulfur atom would contain 16 protons and 16 electrons. The electrons would be distributed as follows: 2 in the first level, 8 in the second level, and 6 in the third level. In order to achieve a full 8 electrons in the third level, the sulfur atom could accept 2 electrons in an ionic bond or share 2 electrons in a covalent bond. Since hydrogen atoms can share 1 electron in a covalent bond, the sulfur atom would form two covalent bonds, one with each of two hydrogen atoms.

47. If a person exhales large amounts of carbon dioxide, the equilibrium will shift to the left, and the level of hydrogen ion in the blood will decrease. A decrease in the amount of hydrogen ion will cause the pH to rise.

48. Since NaCl is an ionic compound, it will dissociate in water to produce equal numbers of sodium ions and chloride ions. Thus each mole of NaCl will produce 2 moles of ions. To prepare a solution containing 1.2 moles of ions, the student should dissolve 0.6 moles of NaCl. The molecular weight of NaCl is the sum of its atomic weights (i.e. 23 + 35.5 = 58.5 gr/mole). Therefore, 0.6 moles x 58.5 gr/mole = 35 gr of NaCl should be added to the solution.

❑ Media Lab Instructor Notes

Web addresses often change. To avoid dead links, we are listing the keywords in parentheses next the to Web Explorations. Simply go to the Companion Website (http://www.prenhall.com/martini), then select the Fifth Edition of Fundamentals of Anatomy and Physiology and search using the key word to locate the current address.

Animations (Website)

- Figure 2-3—Animation with sounds in play/next format. Chemical bonding, ionic bonds; suitable for lecture enhancement during explanation of bonding
- Figure 2-11—Animation in play/next format. Dehydration and hydrolysis reactions, suitable for lecture enhancement during synthesis, catabolism or carbohydrate explanation.
- Figure 2-20—Animation in play/next format. Enzyme catalytic function; suitable for lecture enhancement during explanation of enzyme functioning.

Web Explorations (Overview)

Web Exploration 1 **(pH)**

- *Goal*—experimentation with pH and Hydrogen ion concentrations
- *Description of page*—pH "playground" boxed area with pH and H+ ion readings
- *Expectations of student behavior*—initial reading of page, then some random clicking on arrows before actually understanding the significance of the boxed area; once understood, the student will move quickly to conclusion
- *Instructor's role*—preparatory lecture on pH and ion concentrations, demonstrate how to operate "playground" in lecture?
- *Special notes or further uses*—site may require additional chemistry information (millimole, nanomole relationship, etc.); can be used to design and test mini-experiments

Web Exploration 2 **(ATP)**

- *Goal*—further information on ATP; deeper understanding of energy transfer
- *Description of page*—Molecule of the Month page from Bristol U; short concise information on ATP
- *Expectations of student behavior*—read information, may click on terms or names as they read.
- *Instructor's role*—preparatory instruction on ATP, ADP, AMP and enzymes
- *Special notes or further uses of exploration*—helps with visualization of chemical structures, can move to information on Nobel Prizes for continued exploration

Additional Web Explorations

Should the two explorations found in the text not answer your needs, a third exploration is provided below. Your students do not have direct access to this exploration. You must provide them the address and information in the following paragraph.

Web Exploration 3
Estimated time for completion = 15 minutes

DNA fingerprinting is a technique used to link suspects to crimes, trace heredity, and look for genetic changes in individual samples of tissue. Specifically what is this technique? Review the structure of DNA as it is explained in the text, then go to this Website (http://chemistry.miningco.com/education/chemistry/library/weekly/aa070698.htm) and read the article on DNA fingerprinting. After reading this article, reflect on what you have heard about DNA fingerprinting in the media. Write a short essay defending your position for or against the use of DNA fingerprinting in crime investigations. Share your essay with your classmates, tallying the results. Is there a consensus in your class concerning this technique?

Web Exploration 3 (**DNA FINGERPRINTING**)

- *Goal*—critical thinking / science and media
- *Description of page*—DNA fingerprinting article taken from Chemistry Newsletter 7/6/98
- *Expectations of student behavior*—reading
- *Instructor's role*—interpret difficult passages, define terms, support student thought processes as the material gets more difficult
- *Special notes or further uses of exploration*—page offers many links – most are too detailed for the beginning A&P student. Site upgraded continually, best to check what is linked before class.

Topic Outline				A/V Resources				
Objectives	**Chapter 2** **The Chemical Level of Organization** (page 1 of 4)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	I. Introduction							
1a	**II. Atoms and Molecules**							
	A. Atomic Structure	2-1a		●	●			
	1. Elements and Isotopes	2-1		●	●			
	2. A Weights							
	3. Electrons and Energy Levels	2-2	6a	●	●			
1b	B. Chemical Bonds							
	1. Ionic Bonds	2-3	1a,3a	●	●	●		
	2. Covalent Bonds	2-4,5	4a	●	●			
	3. Hydrogen Bonds	2-6	6b,c	●	●			
	4. States of Matter							
	5. Molecular Weights							
3a	**III. Chemical Reactions**							
	A. Basic Energy Concepts							

Topic Outline				A/V Resources				
Objectives	**Chapter 2** **The Chemical Level of Organization** (page 2 of 4)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	B. Types of Reactions							
	1. Decomposition							
	2. Synthesis							
	3. Exchange							
	C. Reversible Reactions							
3b	D. Enzymes and Chemical Reactions	2-7		●	●			
2b	**IV. Inorganic Compounds**							
2c	A. Water and Its Properties							
	1. Aqueous Solutions	2-8ab		●	●			
	2. Colloids and Suspensions	2-8c	3b	●	●			
2d	3. Hydrogen Ions and Body Fluids	2-9		●	●			
	B. Inorganic Acids and Bases		5a					
	C. Salts							
	D. Buffers and pH Control							

Topic Outline				A/V Resources				
Objectives	**Chapter 2** **The Chemical Level of Organization** (page 3 of 4)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
2e	**V. Organic Compounds**							
	A. Carbohydrates							
	1. Monosaccharides	2-10		●	●			
	2. Disaccharides and Polysaccharides	2-11,12		●	●	●		
	B. Lipids							
	1. Fatty Acids	2-13		●	●			
	2. Eicosanoids	2-14			●			
	3. Glycerides	2-15	4b	●	●			
	4. Steroids	2-16	4c	●	●			
	5. Phospholipids and Glycolipids	2-17	4d	●	●			
	C. Proteins							
	1. Structure of Proteins	2-18,19	1b	●	●			
	2. Protein Shape	2-20	2ab	●	●			
	3. Enzyme Function	2-21	1c	●	●	●		

Objectives	Topic Outline: **Chapter 2 The Chemical Level of Organization** (page 4 of 4)	Figures	Strategies	A/V Resources: Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	4. Glycoproteins and Proteoglycans							
	D. Nucleic Acids							
	1. Structure of Nucleic Acids	2-22	3c		●			
	2. RNA and DNA	2-23	1db	●	●			
	E. High-Energy Compounds	2-24		●	●			
	VI. Chemicals and Cells							

CHAPTER 3

The Cellular Level of Organization

Introduction

The discovery of the cell is probably the key event that led to our mechanistic understanding of life. It is fun and interesting to trace the development of this concept starting with van Leeuwenhoek's conception of the cell as a nondescript box in the late 1600s. From there the cell became a "bag of enzymes," later still the organelles were discovered and then came Lynn Margulis's hypothesis of a eukaryotic cell as a colony of symbiotic organisms. It seems that with every passing decade our conception of the cell becomes more complex. You should strive to leave the student with a sense for how complex and sophisticated a cell is. I emphasize that for every ability we have, there must be a series of cellular specializations to explain it. We are really not much more than the sum of our cells!

Instructional Goals/Learning Objectives

1. To introduce students to **functional cytology.**

   a. *Describe the organelles of a typical cell, and indicate the specific functions of each.*
   b. *Summarize the process of protein synthesis.*
   c. *Explain the functions of the cell nucleus.*
   d. *Discuss the nature and importance of the genetic code.*

2. To provide a clear understanding of **membrane structure and function**, and introduce the general concept of a **membrane potential**, to be built upon in later chapters.

   a. *List the functions of the cell membrane, and the structural features that enable it to perform those functions.*
   b. *Specify the routes by which different ions and molecules can enter or leave a cell, and the factors that may restrict such movement.*
   c. *Describe the various transport mechanisms that cells use to facilitate the absorption or removal of specific substances.*
   d. *Explain the origin and significance of the transmembrane potential.*

3. To familiarize students with the **basic mechanisms for energy production, storage, and manipulation within living cells**.

4. To link biochemical and cytological concepts together in the discussion of **mitosis.**

   a. *Describe the stages of the cell life cycle.*
   b. *Describe the process of mitosis and explain its significance.*
   c. *Define differentiation and explain its importance.*

❑ Teaching Strategies

1. Analogies

a. It serves well to compare the cell to a chemical factory and to consistently draw analogies between the two: from the boss giving orders in the main office which is isolated from the rest of the factory (the DNA in the nucleus surrounded by the nuclear membrane); to the workers (ribosomes) on the assembly lines (RER and SER) in the factory (cytosol) who receive the orders for production from the boss's special messenger (mRNA) and rely on specified raw materials (amino acids or other cytoplasmic molecules) provided by "runners" (tRNA); to the mail room where items are packaged for shipment within the plant or to other factories (the Golgi); to the trams that shuttle the packaged material to the gates of the factory or bring material in from the gates (the vacuoles); to the gates that control shipment in and out (the cellular membrane); to the generator that provides the power for all of the factory activities (the mitochondria). While all factories have the same general component parts, individual factories differ from one another depending upon their specificity of production. At the risk of oversimplification, this analogy seems to avail students with a logical sequence of the organelles and their function, while providing for them a familiar frame of reference.

b. To achieve the image of the look and consistency of typical cells, compare them to balloons filled with a colloid suspension of gelatin and fruit cocktail. They have more structure than a water balloon, but they are "squishable," and the organelles are suspended in place within the cytoplasm just as the fruit is suspended within the gelatin.

c. Compare the phospholipid bilayer to a sandwich: the hydrophilic heads are the bread, and the hydrophobic tails are the filling. To achieve the image of a fluid mosaic membrane of phospholipids with proteins and carbohydrates contained within, create an imaginary visualization of hundreds of ping-pong balls floating on the surface of a pool of water with the occasional larger whiffle ball or foam rubber ball interspersed within the continuous sheet of ping-pong balls.

d. Stress that diffusion, osmosis, filtration, and facilitated diffusion are all passive processes. They require no expenditure of energy; the molecules move down their concentration gradient. In contrast, active transport, endocytosis, and exocytosis are all active processes. They require an expenditure of energy; the molecules or substances move independent of their concentration gradient. These ideas can be illustrated via the following analogy. It's moving day, and the house that you're moving to is just down the hill from the apartment you've been renting. You've boxed up all your belongings, and the boxes are sitting at the top of the hill ready to be carried down. You could just let them slide to the bottom of the hill. This would not expend any energy on your part, because of the gravity gradient that existed down the hill (simple diffusion). Now, suppose you had a couple of dollies to help in the transport of the boxes. The boxes could again slide to the bottom of the hill down the gravity gradient without expenditure of energy, but this time, the wheeled cart would speed up the transport (facilitated diffusion). Since you have only two dollies, and

they each hold only one box, the rate at which you can send boxes down the hill is limited (saturation). Now suppose you discover that one of the boxes you sent down the hill was not your stuff and so it had to be brought back up the hill. You know that you will be able to use the dolly to help in the moving of the box up the hill, but you're going to have to push the box as well since you will be moving against the gravitational pull (active transport). (CONTRIBUTED BY MARY KATHERINE K. LOCKWOOD, Ph.D., UNIVERSITY OF NEW HAMPSHIRE).

e. When introducing the concept of the genetic or triplet code, compare the "reading" of the message of the base sequence in the DNA of each gene to actual reading: the bases = letters, the triplet code = words that mean specific amino acids, and a protein = the concept achieved as a result of the arrangement and number of words put together in a sentence. If you put enough words together, you get a thought or idea (protein) that can be as short as one sentence or as long as several paragraphs (depending upon the size of the gene). Reading the message is like reading letters on a page, not only do we understand that certain letters (bases) together have a meaning that we call a word (triplet code), but stringing words together in a certain order (sequencing) gives a collective meaning to the words (protein). If we change the order of the words, we get a different meaning. For example, "The man sat on the hat," has a very different meaning than "The hat sat on the man," even though both sentences use the same letters and words. In addition, we respond to "signals" when we read: a capital letter means the beginning of a sentence, a period tells us that the sentence is over. Punctuation marks act just as the regulatory triplets within each segment of a gene.

f. The letter-word-sentence analogy can be continued to illustrate point mutations and frame-shift mutations. Consider the message (protein) "I looked all over for the cat. It was on the back of the sofa." If a mutation occurs at a specific letter (nucleotide) changing the "t" in cat to an "h" the result would be a completely different message. A deletion of a base resulting in a frame-shift mutation can be just as problematic. Consider the triplet code message: "Theredhatforthemanwastoobig." Separated into triplet codes it reads, "The/red/hat/for/the/man/was/ too/big." But if one nucleotide was deleted (the "r" in red), the message would read: "The/edh/atf/ort/hem/anw/ast/oob/ig." Both kinds of mutations will result in the production of either a wrong protein or no protein, the repercussions of which could be disease or even death!

g. Before proceeding to the explanation of transcription and translation, it would be helpful to remind the students of the factory analogy. Suppose the factory boss (DNA) decides to send a message out to the workers located at the protein assembly line (ribosomes on the RER) regarding what proteins they should be assembling. But, of course, he is the boss, and much too busy to leave his office (the nucleus) just to bring the message out to the workers personally. He calls on his trusty messengers (mRNA) to relay the message for him. He has the messengers copy his orders, but since he is concerned about industrial espionage, he tells them to transcribe the orders into a code. Then each messenger puts the code on (codon) his back to carry the message out of the office to the assembly line. Once at the assembly line, the code has to be translated so that the workers will know what amino acids to link together

to produce the needed proteins. Specially trained runners (tRNA) read the code, translate it to the original message (anticodon), which they in turn translate to the appropriate raw material (amino acid). Each runner picks up her amino acid package from the factory floor and transfers it over to the assembly line, so that it may be hooked up by the workers to the previous amino acid. As soon as she makes the transfer, she reads the next word of the code, translates it, and proceeds as before. The runners continue until the message in the code says "STOP HERE."

2. Demonstrations

a. Identifying the different mitotic stages through projection slides in lecture or lab will help students develop their abilities to make sense of what they see through the microscope.

b. The concept of "increased surface area" and its structural/functional importance is difficult for students to fully appreciate. To demonstrate this concept, lay a piece of notebook paper on a table, and point out that the paper is occupying an 8.5" x 11" (93.5 sq. inches) space on the surface of the table. Now, if you tape two pieces of paper together, end-to-end, they occupy an 8.5" x 22" (187 sq. inches) space, twice as much as the single sheet. If, however, you accordion-pleat the doubled paper, you can illustrate that the same 8.5" x 22" (187 sq. inches) sheet will occupy only an 8.5" x 11" (93.5 sq. inches) space. Folding the paper has allowed you to double the surface area in the same amount of space as the single sheet of paper (or, in other words, you have the same amount of paper occupying only half of its original space). In areas of the body where work gets done across a surface membrane, such as the absorption surface of the intestines, the bigger the surface area, the more work can be done; however, the intestine must fit into the finite space of the abdominal cavity. By increasing the inside surface area of the intestine with folds, villi, and microvilli, the magnitude of surface area is many times more than the physical space the intestine occupies. The same phenomenon is seen with the cristae of mitochondria.

3. Vocabulary Aids

a. Be careful to make a distinction between semipermeable and selectively permeable. Any physical barrier, living or non-living, can be semipermeable by virtue of the size of the openings or pores within the barrier. Only living membranes can be selectively permeable, since they can change their permeability and select for or against a substance depending upon the circumstances. The cells of the tubules of the kidney can change their permeability allowing us to produce more or less urine as needed.

b. When defining the prefixes iso-, hypo-, and hyper-, associate the "s" in iso with the "s" in the word "same," the "o" in hypo with the "o," in the word "low" (it rhymes with hypo as well), and use the example of someone being hyperactive to illustrate that hyper means more. A hypodermic needle is used to inject below the dermis.

c. *Centrioles* function in division of the cell's nucleus, and therefore are absent from differentiated cells that are amitotic. The *centrosome* refers to the centrioles and the specialized cytoplasm immediately surrounding the centrioles.

d. A commonly used mnemonic device to help remember the major stages of the cell's life cycle is "I Pee on the MAT." (Interphase, Prophase, Metaphase, Anaphase, Telophase). Other word associations to remember for the mitotic stages: Pro means #1 or first, so it is the first stage. Associate the "m" in metaphase with "middle," which describes the location of the chromatids during metaphase. Associate the "a" in anaphase with "away," which describes the activity of the sister chromatids as they pull away from each other. Remember the "te" in telophase for "The End," to associate it as the last of the four stages.

e. A stem cell gets its name, because it's the beginning of a line of cellular growth, like the main stem of a plant that eventually differentiates and grows into branches, leaves, and flowers.

4. Common Student Misconceptions/Problems

a. In spite of memorizing that cells are the smallest unit of life, and understanding that events which occur on a cellular level will affect what occurs on an organismal level, students tend to come away from the study of cell structure having learned all the pieces that comprise a cell but not having developed a cognitive sense of a "big picture" or that those pieces fit together to work in unison.

b. Factors influencing diffusion rate include:

Distance
Size of the gradient
Molecule size
Temperature
Electrical forces

Equilibrium does not mean that diffusion does not continue, only that there is no longer a concentration gradient and hence no **net** movement.

c. Make sure that it is understood that the words isotonic, hypotonic, and hypertonic are in reference to the behavior of a cell and not specifically to the physical chemical properties of the solution. By definition, a solution is isotonic for a particular cell type if that cell doesn't swell when placed in the solution. The solution is not necessarily isosmotic to the cell's contents.

d. It is common for students to confuse flagella, cilia, and microvilli. A summary table comparing each structure's appearance, relative size, density, structural make-up, and function with an example of each, might alleviate some of the confusion. Flagella are long, whip-like appendages composed of microtubules (in eukaryotes). They are used by the cells to propel them from place to place (locomotion). Example: a sperm cell is the only human flagellate. Cilia are small, hair-like projections on the surface of the

cell, also composed of microtubules. Because they are so numerous, they often give the cell a "fuzzy" appearance. In humans, they beat, or wave, in a coordinated manner to sweep extracellular substances across the cell's surface. Example: cells lining the trachea or cells of the Fallopian tubes. Microvilli are actual folds in the cell's membrane in order to increase surface area. They are not appendages, and although they may wiggle a bit, they are supported by microfilaments, not microtubules. They do not exhibit the highly stereotyped movements of cilia and flagella.

e. The term interphase is somewhat misleading since it implies a short phase stuck in between other activities. Point out that this couldn't be further from the truth when examining what actually goes on during interphase and considering that it comprises most of the cell's life span.

f. It is worth dissuading the students from the common misconception that DNA is a blueprint for an organism. Richard Dawkins (see his book, *The Blind Watchmaker*) has gone to great lengths to point out that a more apt analogy is that DNA is like a recipe. The key difference is that a blueprint gives complete and explicit instructions for the placement of every part in the final product. A recipe gives a set of instructions that when followed will result in the desired final product. In principal, a blueprint could be reconstructed from a study of the parts of the final product, a recipe could not.

5. Lecture ideas

a. Osmosis refers to diffusion of water through a membrane. Osmosis occurs across membranes that are not freely permeable to solutes, but are permeable to water. Water flows toward solutions of higher solute concentration, since such solutions have a lower water concentration.

b. Vesicular transport involves "macro" movement as compared to the "micro" movement of diffusion, osmosis, etc. Thus, the membrane becomes a physical part of the transport process (as opposed to solutes moving through the membrane).

c. Functions of microfilaments include:

Anchor the cytoskeleton to integral membrane proteins
Interact with other filaments to produce cellular movement

Functions of intermediate filaments include:

Provide strength
Stabilize position of other organelles
Transport materials within the cytoplasm

Functions of microtubules include:

Provide cell strength, rigidity, and anchoring organelles
Alter shape of cell, perhaps assisting in cell movement
Can relocate organelles within the cell
Form the spindle apparatus for cell division
Form centrioles, cilia, and flagella

d. The function of microvilli is to increase cell surface area; they are usually located on cells that are involved in transporting substances across the cellular membrane from extracellular fluid. Microvilli contain microfilaments.

e. Functions of the endoplasmic reticulum include:

Synthesis of proteins, carbohydrates, and lipids
Storage of materials
Transport of materials within the cell
Detoxification of drugs or toxins

Functions specific to smooth ER include:

Synthesis of phospholipids and cholesterol
Synthesis of steroid hormones, in gonads and adrenals
Synthesis and storage of glycerides, in liver and fat cells
Detoxification of drugs, in liver and kidney cells
Synthesis and storage of glycogen, in muscle and liver cells

Functions specific to rough ER include:

Synthesis and modification of proteins
Packaging proteins for transport to the Golgi

Functions of the Golgi include:

Synthesis and packaging of secretions for exocytosis
Renewal or modification of the cell membrane
Packaging of enzymes for use in the cytosol

f. Human DNA is always bound to histone proteins.

Nucleosomes are the sites at which DNA wraps around histones.

In interphase cells, each strand of DNA, with its histone proteins, has a characteristic fine filamentous appearance, and is called extended chromatin.

Nucleoli are composed of histones, RNA, and enzymes, coiled around the DNA regions that code for ribosomal proteins and ribosomal RNA.

The chromatin condenses or supercoils only during mitosis, when it exhibits the characteristic chromosome appearance.

g. To illustrate the details of protein synthesis, as well as provide a brief summary, write on the board a segment of DNA bases:

TACAAAACACGACGGAATACT

Ask the class to provide the mRNA codon:

AUGUUUUGUGCUGCCUUAUGA

Divide the codon into its triplets and convert to the tRNA anticodon:

UAC AAA ACA CGA CGG AAU ACU

Rewrite the original DNA base sequence below the anticodon to illustrate that the anticodon is really the same as the DNA message (with the substitution of U for T). Thus, DNA really does directly control synthesis of structural proteins and enzymes. Using the table in Figure 3-24, convert the anticodon message to a polypeptide:

(MET) PHE-CYS-ALA-ALA-LEU (TERM)

h. The result of mitosis must be two identical cells. Identical means genetically identical; i.e., each new cell has exactly the same chromosomal make-up as the original cell; there is no variation. Ask the students what they think the purpose of mitosis is:

1. *growth*-we obviously have grown proportionally from infancy.
2. *replacement*-as old cells die, we need a way of replacing them with identical cells.
3. *repair*-if new cells couldn't take the place of damaged cells, we'd look like Swiss cheese by the time we reached adolescence!

Answers to End of Chapter Exercises

Level 1: Reviewing Facts and Terms

1. c
2. c
3. d
4. a
5. a
6. d
7. a
8. c
9. d
10. b
11. b

12. (1) Cells are the building blocks of all plants and animals. (2) Cells are produced by the division of pre-existing cells. (3) Cells are the smallest units that perform all vital physiological functions. (4) Each cell maintains homeostasis at the cellular level. (5) Homeostasis at the tissue, organ, system and individual level reflect the combined and coordinated actions of many cells.

13. (1) physical isolation (2) regulation of exchange with the environment (3) sensitivity (4) structural support

14. Membrane proteins function as receptors, channels, carriers, enzymes, anchors and identifiers.

15. (1) diffusion (2) filtration (3) carrier mediated transport (4) vesicular transport

16. (1) distance (2) size of the gradient (3) molecule size (4) temperature

17. (1) Osmosis is the diffusion of water molecules across a membrane. (2) Osmosis occurs across a selectively permeable membrane that is freely permeable to water, but not freely permeable to solutes. (3) In osmosis, water will flow across a membrane toward the solution that has the highest concentration of solutes.

18. (a) Nonmembranous: cytoskeleton, microvilli, centrioles, cilia, flagella, and ribosomes. (b) Membranous: nucleus, mitochondria, endoplasmic reticulum, Golgi apparatus, liposomes and peroxisomes.

19. (1) synthesis of proteins, carbohydrates, and lipids (2) storage of absorbed or synthesized molecules (3) transport of materials (4) detoxification of drugs or toxins

20. (1) prophase (2) metaphase (3) anaphase (4) telophase

Level 2: Reviewing Concepts

21. b
22. a
25. b
26. c
25. c

26. specificity, saturation, regulation, may be active or passive, one ion or molecule or multiple numbers of solutes may be transported simultaneously.

27. (a) Similarities: both processes utilize carrier proteins and exhibit saturation. (b) Differences: Facilitated diffusion is passive, does not expend ATP, and requires a concentration gradient, whereas active transport is active, expends ATP, does not require a concentration gradient.

28. By ejecting sodium ions from the cytosol and reclaiming potassium ions from the extracellular fluid in a ratio of 3:2, the sodium-potassium pump maintains the negative resting membrane potential.

29. Cytosol: high concentration of K^+; Interstitial fluid-high concentration of Na^+; is a colloid containing a high concentration of suspended proteins; contains small quantities of carbohydrates and large reserves of amino acids and lipids; may contain insoluble materials known as inclusions.

30. Transcription: RNA polymerase uses genetic information to assemble a strand of mRNA; Translation: ribosomes use information carried by the mRNA strand to assemble functional proteins.

31. G_0: normal cell functions; G_1: cell growth, duplication of organelles, protein synthesis; S: DNA replication, synthesis of histones; G_2: protein synthesis

32. Prophase: chromatin condenses and chromosomes become visible, centrioles migrate to opposite poles of the cell and spindle fibers develop; nuclear membrane disintegrates; Metaphase: chromatids attach to spindle fibers and line up along the metaphase plate; Anaphase: chromatids separate and migrate toward opposite poles of the cell; Telophase: nuclear membrane re-forms, chromosomes disappear as chromatin relaxes; nucleoli reappear

33. (a) Cytokinesis is the cytoplasmic movement that separates two daughter cells (b) It completes mitosis.

Level 3: Critical Thinking/Clinical Application

34. This process would be facilitated diffusion. Facilitated diffusion requires a carrier molecule, but does not require cellular energy. The energy for the process is provided by the concentration gradient for the substance being transported. When all of the carriers are actively involved in transport, the rate of transport plateaus or reaches a saturation point.

35. Solution A must have initially had more solutes than solution B. As a result, water moved by osmosis across the selectively permeable membrane from side B to side A, increasing the fluid level on side A.

36. For the dialysis fluid to remove urea without removing water, it should have little if any urea and be slightly hypertonic. Since urea is a small molecule, it should diffuse through the dialysis membrane from an area of high concentration (the blood) to an area of low concentration (the dialysis fluid). If the dialysis fluid is slightly hypertonic, then some of the solute molecules

should diffuse into the blood. This would replace the solute removed by the diffusion of urea, and prevent water from leaving the blood, thus maintaining blood volume.

❑ Media Lab Instructor Notes

Web addresses often change. To avoid dead links, we are listing the keywords in parentheses next the to Web Explorations. Simply go to the Companion Website (http://www.prenhall.com/martini), then select the Fifth Edition of Fundamentals of Anatomy and Physiology and search using the key word to locate the current address.

Animations (Website)

- Figure 3-18 and 3-19—Animation in play/next format. ER to Golgi to Lysosome or secretory vesicles flow; suitable for lecture enhancement during explanation of organelle interactions
- Figure 3-23 and 3-25—Animation in play/next format. Transcription and translation as one continuous process, suitable for lecture enhancement explanation transcription, translation and the continuous series of events.

Web Explorations (Overview)
Web Exploration 1 (**REPLICATION**)

- *Goal*—experimentation / critical thinking in DNA functioning
- *Description of page*—short descriptive page linked to experiment
- *Expectations of student behavior*—read first page, click on experiment and move through pre-determined steps (can't make mistakes—program won't allow mis-matches)
- *Instructor's role*—introduce DNA, base pairing, transcription and translation, lead students through first attempts
- *Special notes or further uses of exploration*—good for classroom discussion; further investigation on paper with ability to make mutations

Web Exploration 2 (**MITOSIS**)

- *Goal*—critical thinking beyond text / cell cycle control
- *Description of page*—descriptive essay on mitotic control, with glossary and further descriptive pages linked where appropriate
- *Expectations of student behavior*—read information, click on further links
- *Instructor's role*—introduce cell cycle and biochemical controls, provide feedback on thought processes
- *Special notes or further uses of exploration*—explain purpose fully to avoid students clicking links before task completed; follow links to review mitosis or DNA replication

Additional Web Explorations
Should the two explorations found in the text not answer your needs, a third exploration is provided below. Your students do not have direct access to this exploration. You must provide them the address and information in the following paragraph.

Web Exploration 3
Estimated time for completion = 5 minutes

The cell membrane serves as the boundary between the interstitial fluid and the intracellular environment. Through the process of osmosis, water molecules travel across this boundary. To see how these molecules react, go to this Website (http://biology.unm.edu/~lewisp/osmosis/Osmosis.html) and watch the demonstration for two or three minutes. Can you relate this to the cell membrane? Do molecules move in both directions across the artificial membrane? Does the movement of the molecules cease when equal? Will the concentration of water molecules on either side of the membrane ever be equal? If you wish, share your answers to these questions with your classmates using the communications tools available on the Companion Website.

Web Exploration 3 (**OSMOSIS**)

- *Goal*—further clarification of osmosis, cell membrane function
- *Description of page*—short prose with active upper window demonstrating molecular movement
- *Expectations of student behavior*—read and watch animation a few minutes
- *Instructor's role*—clear explanation of cell membrane and osmosis, pose proper questions to enhance student observations; encourage group observations
- *Special notes or further uses of exploration*—easy way to introduce osmosis and semipermeable membrane in lecture format

Topic Outline				A/V Resources				
Objectives	**Chapter 3** **The Cellular Level of Organization** (page 1 of 4)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	I. Introduction	3-1	1a, 4a		●			
	II. Studying Cells		1b					
1a	A. An Overview of Cellular Anatomy	3-2		●	●			●
2a	**III. The Cell Membrane**							
	A. Membrane Structure		1c					
	1. Membrane Lipids	3-3		●	●		●	●
	2. Membrane Proteins	3-4						
2b	3. Membrane Carbohydrates							
	B. Membrane Permeability		1d, 3a					
	1. Diffusion	3-5,6,7,8a	3b, 4bc, 5a	●	●		●	
	2. Filtration						●	
2c	3. Carrier-Mediated Transport	3-9,10,11		●	●		●	
	4. Vesicular Transport	3-12,13ab	5b	●	●			
2d	5. Transmembrane Potential						●	

Topic Outline				A/V Resources				
Objectives	**Chapter 3** **The Cellular Level of Organization** (page 2 of 4)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	IV. The Cytoplasm							
	A. The Cytosol							
	B. Organelles		4d					
	1. The Cytoskeleton	3-14a	5c	●	●			
	2. Microvilli	3-14b	2b, 5d		●			
	3. Centrioles	3-15a	3c		●			
	4. Cilla	3-15bc	3c	●	●			
	5. Flagella		3c					
	6. Ribosomes	3-16		●	●			
	7. The Endoplasmic Reticulum	3-17	4e	●	●			
	8. The Golgi Apparatus	3-18,19	4e	●	●	●		
	9. Lysosomes	3-18b,19a		●	●	●		
	10. Peroxisomes							
3	11. Mitochondria	3-20		●				

TOPIC OUTLINE

Objectives	Chapter 3 The Cellular Level of Organization (page 3 of 4)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
				A/V RESOURCES				
1c	**V. The Nucleus**	3-21	4f	●	●			●
	A. Chromosome Structure	3-22	4f	●	●			
1d	B. The Genetic Code		1e					
1b	C. Gene Activation and Protein Synthesis		1g					
	1. The Transcription of mRNA	3-23		●	●	●	●	
	2. Translation	3-24,25	1f	●	●	●		
	D. DNA and the Control of Cell Structure and Function		5g					
4a	**VI. The Cell Life Cycle**	3-26	3d	●	●			
	A. Interphase							
	1. The G_1 Phase							
	2. The S Phase	3-27		●	●			
	3. The G_2 Phase							
4b	B. Mitosis	3-28	2a, 5h	●	●			
	1. Stage 1: Prophase							

Objectives	TOPIC OUTLINE **Chapter 3** **The Cellular Level of Organization** (page 4 of 4)	Figures	Strategies	A/V RESOURCES: Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	2. Stage 2: Metaphase							
	3. Stage 3: Anaphase							
	4. Stage 4: Telophase							
	C. Cytokinesis							
	D. The Mitotic Rate and Energetics							
	E. Regulation of the Cell Life Cycle							
	1. Cell Division and Cancer	3-29			●			
4c	**VII. Cell Diversity and Differentiation**		3e					

CHAPTER 4

The Tissue Level of Organization

Introduction

You might start the discussion of tissues by pointing out the fact that cancers of muscle and brain are relatively rare while cancers of lung, gut and the reproductive tracts are much more common. Why is this? Next ask why we can replace damaged liver or kidney but not muscle or brain (there's that combination again). Why can't we regenerate major parts of our bodies while other organisms can? The answer to these questions lies in the special needs of the different tissue types. We are composed of something like 200 different cell types. These cells are organized into groupings that accomplish specific functions. Students are familiar with cells and with organs but not with the intermediate level of organization. Point out how different organs need to accomplish many similar functions. For example, both the heart, the gut and the uterus all need to generate force. Another example is that gut, kidney and blood vessels all need to transport substances between compartments. Also, all organs need a structural glue that holds the whole thing together. This motivational introduction might help the students appreciate better what is going on at this organizational level.

Instructional Goals/Learning Objectives

1. To familiarize students with **the major tissue types** and **their functional properties**.

   a. *Discuss the types and functions of epithelial cells.*
   b. *Describe the relationship between form and function for each epithelial type.*
   c. *Compare the structures and functions of the various types of connective tissues.*
   d. *Describe the three types of skeletal muscle tissue and their special structural features.*
   e. *Discuss the basic structure and role of neural tissue.*
   f. *Describe how aging affects the tissues of the body.*

2. To demonstrate **how different tissue types interact to create organs.**

   a. *Describe how connective tissue establishes the framework of the body.*
   b. *Explain how epithelial and connective tissues combine to form four different types of membranes and specify the functions of each.*

❑ Teaching Strategies

1. Analogies

a. Parallels can be made between the organizational levels of cells and tissues within organs and the instruments and sections within an orchestra. An orchestra is made up of many individual instruments (cells), but they are not randomly put together. They are grouped into sections (tissues) according to the sound and construction of the instruments: the strings, the reeds, the brass, and the percussion. It may appear as if each instrument is playing as an individual, but in fact, they are synchronized, and with the help of a conductor, the individual sections can be played in such a way as to make one large, harmonious orchestra (organ).

b. This might be an appropriate time to discuss the distinction between "inside" and "outside" the body. Ask the students to visualize what would happen if they were miniaturized and found themselves walking along a mucous membrane. If they walked long enough, they would eventually reach the outside of the body. In this case, were they ever really inside the body? Emphasize that a substance must cross a membrane to be truly inside. Several examples can be given to illustrate this point: air in the alveoli of our lungs is not inside until it crosses the mucous membrane, food in our intestine is not inside until it crosses the mucous membrane, fluid in the kidney becomes outside as soon as it moves from the capillaries to the tubules. If you put your finger in the hole of a donut, is it actually in the donut? (CONTRIBUTED BY STEVE N. TRAUTWEIN, Ph.D.; SOUTHEAST MISSOURI STATE UNIVERSITY.)

c. Distinguish between cell adhesion molecules (CAMs) and specialized cell junctions: CAMs usually attach one layer of cells (a membrane) to another layer, while specialized cell junctions are between individual cells. Individual ceramic tiles on a bathroom floor will be glued together with grout (cell junctions), but the sheet of tiles is cemented onto the subflooring (CAMs).

d. Glandular Epithelia: Stress the structural and functional differences between endocrine and exocrine glands. An endocrine gland is structurally like a saturated sponge; the chemical oozes out of the cells into the interstitial space where it can diffuse across capillary walls into the blood. An exocrine gland is more like a faucet with a hose attached; the cells of the faucet produce the chemical, and it travels down the hose to its target site.

2. Vocabulary Aids

a. Germinative cells are cells that germinate and grow like seeds that can be germinated.

b. Squamous Epithelia: associate the word "squamous" with the word "squashed."

c. Emphasize that the word stratified means layered, associate it with the stratosphere, a layer of the earth's atmosphere, or with the layers in the earth's surface.

d. Ciliated pseudostratified columnar epithelium is a tongue-twister for most students. Use a mnemonic for CPCE to help them remember. For example, Can People Cook Eggplant, Caged Piranha Create Excitement, Candy Pleases Chocolate Excites, Creative People Can Excel, etc. (the students may offer suggestions).

e. Associating the word lacuna with a Polynesian word for a little house (it houses the cells). Emphasize that the holes housing osteocytes are called lacunae, as in cartilage.

f. Canaliculi means "little canal," it brings to mind a type of Italian pasta.

g. There is frequent confusion between "stratified" and "striated." Remind them of the meaning of stratified and to what it refers. Associate the sound of the word striated with the sound of the word striped.

h. 'Stress that the conduction pathway down the length of a neuron is one-way: dendrites carry impulses to a cell body; axons carry impulses away from the cell body. Associate the "t" in dendrite with "toward" and the "a" in axon with "away."

3. Applications

a. Collagen fibers are the fibers that skin cream ads claim to "replenish."

4. Common Student Misconceptions/Problems

a. As a result of previous exposure to high school biology classes and information studied thus far in this text, most students have an adequate concept of a cell. In addition, they have probably assimilated a demonstrable notion of an organ. Most could even identify or give examples of several organs. Where their understanding seems to sag is the connection between the two; i.e., the tissues. Be prepared to have to bridge the conceptual gap between the cellular and organ levels of organization (for many students, it will be the first time the word tissue doesn't mean something in which you blow your nose). Ironically, it is at this organizational level that structural and functional interdependencies become so evident. Oftentimes, examining detailed tissue arrangements and activities will provide insights into organ and organ system operations. Diseases often occur at a tissue level, even though signs and symptoms may not become evident until the organ is affected. One could argue that if tissues are the "building blocks" of organs, then it is only by first understanding the function of those tissues that we can begin to develop a functional image of an organ.

b. In spite of how different organs appear from one another, if they were disassembled into tissues, and the tissues were sorted into "piles" based on their basic function, there would be only four groups! The abstraction that everything in our body can be categorized into just four basic tissue types is somewhat baffling to most students given how apparently different a brain is from a heart, or a stomach is from a muscle. It is beneficial to spend some time illustrating this concept and underscoring the relationship between structural features of tissues and their functions.

c. Point out that although connective tissue seems to be a conglomeration of a tremendous assortment of unrelated tissues, all classifications of connective tissue are

functionally and structurally similar. Structurally, they are composed of an acellular background substance, cells that sit within that background, and protein fibers that help give the background support. The concept of an acellular matrix will be difficult for the students to grasp, since they have always been told that all living things are made of cells. Compare the matrix and cells to the keyboard of a computer. The molded, plastic panel has no direct input to the computer; its function is to provide a background support for the keys and wiring within. The keys, on the other hand, are functionally important for operating the computer, and it is the arrangement of the keys that determine the shape of the panel. Functionally, connective tissue provides support, framework, and protection.

5. Lecture ideas

a. Present this scenario, "Suppose I was a professional tailor, and you came to me to ask me to make you a shirt. I told you that I would be glad to do so, and while I have all the necessary equipment and patterns, you must go to the fabric store to purchase the materials that would actually go into the make-up of the shirt. What would you buy?" After some coaxing and manipulating, you can get the students to identify materials in four basic functional categories, which you should write on the board: 1) fabric or cloth, something that would be used to generate the structural basis of the shirt 2) thread, something to attach the pieces of the fabric together 3) buttons or zippers, something that acts as a closure once the shirt is on 4) trim, something that can be used as ornamentation to adorn the shirt. Point out that each item is distinguishable from the other categories by virtue of its function. Now pose the following: "Suppose you wanted me to make some jeans to go with the shirt; what materials would you buy?" and again, "Now suppose I was to make a bookbag for you; what materials would I need?" After the students list the same functional categories, respond in disbelief, "You mean that it requires the same categories to make all these items? How can that be? They look so different from each other! And a bookbag isn't even an article of clothing! Yet I feel sure that you would never confuse the three (depending upon how heavily you partied the night before)." Now ask, "Would you use the same kind of thread in the bookbag as you used in the shirt? What about the fabric?" The significant parallels to be made are as follows:

1. An endless number of combinations can be made with the same four basic categories, and each combination will vary in its structure, depending upon its function.

2. Each category is distinct from the others by virtue of its function; and therefore, it is an essential component in the make-up of any combination.

3. There can be subtle differences or specialized structures within a category depending upon the specific function required of the category.

b. Describe each type of specialized cell junction, emphasize the "logic" of the structure related to its function. Have the students draw each junction type, describe its function, and give an example of location.

1. Cell adhesion molecules (CAMs) are transmembrane proteins that attach large areas of opposing cell membranes. For example, CAMs attach the base of epithelia to the underlying basement membrane.

2. Gap junctions consist of interlocking membrane proteins, that allow ions and small molecules to pass directly from one cell to another. Gap junctions are common in cardiac and smooth muscle tissues.

3. Tight junctions are formed by fusion of the lipid layers of neighboring cell membranes. These are the strongest junctions, and they are also water-tight. Tight junctions exist in exposed surfaces of cells lining the digestive tract.

4. Intermediate junctions are held together by a thick layer of proteoglycans, known as intercellular cement, reinforced by microfilaments. "Intermediate" refers to the characteristics that are similar but not identical to those of various other types of junctions.

5. Desmosomes are formed from a thin layer of proteoglycans reinforced by intermediate filaments, resulting in a very strong junction. They are especially abundant in superficial layers of skin.

6. After describing the general and specialized cell junctions listed above, tell the students that between any two given cells, more than one type of junction may exist. A good example of this is the intercalated disc of cardiac muscle cells, which are formed from both gap junctions (to allow synchrony of electrical activity) and desmosomes (to resist the strong stretching forces as the heart chambers fill with blood).

c. Classification of Epithelia: With the description of each type of epithelial tissue, emphasize the "logic" of the structure related to its function. Have the students draw each type, describe its function, and give an example of location. Make sure that the example is specific; i.e., do not accept "lung" as a location for simple squamous epithelium, since the lung is made up of many kinds of tissues. "Lining the alveoli within the lung" would be a more correct answer.

d. It is important to make the student appreciate the uniqueness of connective tissues, in both their wide distribution throughout the body, and the large volume occupied by extracellular substances rather than cells. With the description of each type of connective tissue, emphasize the "logic" of the structure related to its function. Have the students draw each type, describe its function, and give an example of location. As with Epithelia, make sure that the example is specific. Indicate that connective tissue is classified based upon the consistency of the ground substance. Supporting connective tissues are able to provide support, because their matrix is so firm. The matrix of cartilage is unique, because while it is firm enough to support weight, it is flexible and will bend or compress under pressure. Imagine the consistency of gummy candy. The density of the matrix requires that structural "holes" be made to

house the chondrocytes, like Swiss cheese. Cartilage is classified according to the type of fibers in the ground substance. Thin fibrils go to make up the loose network of collagen in hyaline cartilage. It appears smooth as glass (hence the name), and is particularly appropriate at the ends of bones to help reduce friction. The cartilage on the end of a chicken breast bone is a good example of hyaline cartilage, and one with which most students are familiar.

e. Muscle tissue is the only tissue capable of contracting when appropriately stimulated. The cells of muscle tissue are very different in appearance from epithelial or connective tissues cells; they are long and string-like. With the description of each type of muscle tissue, emphasize the "logic" of the structure related to its function. Have the students draw each type, describe its function, and give an example of location. As with Epithelia and Connective Tissues, make sure that the example is specific.

f. As with the introduction into the other tissue types, remind the students that nervous tissue is unique and distinct from the other three tissue categories, because it is the only tissue that can convert an electrical impulse into a chemical signal to communicate and hence control other cells. Point out that this occurs at the synapse. Have the students draw each type of nerve cell, describe its function, and give an example of location.

❑ Answers to End of Chapter Exercises

Level 1: Reviewing Facts and Terms

1. j
2. g
3. o
4. m
5. a
6. t
7. c
8. p
9. b
10. f
11. i
12. e
13. k
14. h
15. s
16. n
17. d
18. l
19. r
20. q
21. a
22. c
23. d
24. c
25. c
26. b
27. d
28. d
29. b
30. c
31. c
32. a
33. d
34. b
35. a
36. b

37. (1) cellularity: epithelia consist mainly of cells, rather than extracellular materials. (2) polarity: an epithelium always has a free surface exposed to the external environment or to some internal chamber or passageway. (3) avascularity: epitheilia have no blood vessels. (5) regeneration: epithelial cells are continuously replaced through division of stem cells

38. (1) provide physical protection (2) control permeability (3) provide sensations (4) produce specialized secretions

39. (1) tight junctions (2) desmosomes (3) gap junctions

40. (1) simple (2)stratified (3)transitional

41. (1) squamous (2) cuboidal (3) columnar

42. (1) merocrine (2) apocrine (3) holocrine

43. (1) specialized cells (2) extracellular protein fibers (3) a fluid ground substance

44. (1) establish a structural framework for the body (2) transport fluids in the body (3) provide protection (4) support, surround and interconnect other tissue types (5) store energy (6) defend the body against invasion by microorganisms

45. Fluid connective tissues are blood and lymph. They have a liquid matrix, and the proteins are held in solution. Supporting connective tissues are cartilage and bone. They have a firm, dense matrix that contains large, insoluble fibers.

46. (1) collagen (2) reticular (2) elastic

47. (1) tendons (2) aponeuroses (3) elastic tissue (4) ligaments

48. (1) hyaline (b) elastic (c) fibrocartilage

49. (1) mucous (2) serous (3) cutaneous (4) synovial

50. fluid formed on the surface of a serous membrane; pleural fluid, pericardial fluid, peritoneal fluid; prevent friction between walls of the cavities and surfaces of the organs

51. (1) smooth (2) skeletal (3) cardiac

52. (1) neurons and neuroglia (2) The neurons transmit electrical impulses in the form of changes in the transmembrane potential. The neurologia comprise several kinds of supporting cells, and play a role in providing nutrients to neurons.

Level 2: Reviewing Concepts

53. a

54. Substances are moved over the epithelial surface by the synchronized beating of cilia, like a continuously moving escalator. The ciliated epithelium that lines the respiratory tract moves mucus, which has trapped dust particles from inhaled air, up from the lungs and toward the throat, where it can then be swallowed and eventually eliminated from the body.

55. The process of holocrine secretion destroys the gland cell. During holocrine secretion, the entire cell becomes packed with secretory products and then bursts apart, releasing the secretion but killing the cell. The gland cells must be replaced by the division of stem cells.

56. Exocrine secretions are secreted onto a surface or outward through a duct. Endocrine secretions are secreted by ductless glands into surrounding tissues. The secretions are called hormones, which usually diffuse into the blood for distribution to the other parts of the body.

57. Tight junctions block the passage of water or solutes between the cells. In the digestive system these junctions keep enzymes, acids and wastes from damaging delicate underlying tissues.

58. Intercellular connections called desmosomes are most abundant in superficial layers of skin. Desmosomes create links locking cells together, causing dead skin cells to shed in thick sheets.

59. The extensive connections between cells formed by junctional complexes, intercellular cement, and physical interlocking hold the skin cells together and may deny access to chemicals or pathogens that may cover their free surfaces. If the skin is damaged or the connections broken, infection can easily occur.

60. In infants and young children the adipose tissue in specific areas of the upper body is different from most of the adipose tissue in the adult. This tissue is called brown fat. It is highly vascularized and the fat cells contain many mitochondria. When stimulated by the nervous system, lipid breakdown accelerates and the cells do not capture the released energy; the energy radiates into the surrounding tissues as heat. The heat warms the circulating blood, which distributes it throughout the body. In this way an infant can accelerate metabolic heat generation by 100% very quickly.

61. Adipocytes (fat cells) are metabolically active cells. Their lipids are continually being broken down and replaced. During a weight loss program nutrients are scarce, causing the fat cells to decrease in size. Since the cells are not killed but merely reduced in size, if they are fed they will increase in size and the lost weight will be regained, in the same locations.

62. Cartilage is avascular because chondrocytes produce a chemical that discourages the formation of blood vessels. This makes nutrient and oxygen delivery difficult. In adults, interstitial and appositional growth do not occur, therefore there is no division of chondrocytes or differentiation of the inner cells of the perichondrium into chondrocytes. Both the avascularity and the lack of division and differentiation contribute to the poor healing of cartilage.

63. Cutaneous membranes are thick, relatively waterproof, and usually dry.

64. Cardiac muscle fibers are incapable of dividing and unlike skeletal muscle fibers, cardiac tissue does not contain satellite cells. Therefore, regeneration of damaged or diseased heart tissue is not possible.

65. Elastic ligaments are found along the spinal column, where they are important in stabilizing the position of the vertebrae. It is the elasticity of the elastic ligaments that allows the spine to bend and straighten easily.

Level 3: Critical Thinking/Clinical Application

66. Since apocrine secretions are released by pinching off a portion of the secreting cell, you could analyze for the presence of cell membranes, specifically the phospholipids found in cell membranes. Merocrine secretions do not contain any portion of the cell so they would lack any membrane constituents.

67. The respiratory passages are lined by pseudostratified columnar epithelium that has a ciliated surface. This type of epithelium also contains many goblet cells that produce mucus. The mucus traps debris and foreign material that is moved by the beating cilia to the pharynx to be swallowed. Chronic smoking initially paralyzes the cilia, resulting in a buildup of mucus in the airways. The hot air and particulates sear the cilia and burn them off. The epithelium is also damaged by the heat and responds by producing even more mucus that unfortunately cannot be moved due to lack of cilia. The only way that the respiratory system can clear the debris and mucus is with forceful bursts of air, known as coughing.

68. Since animal intestines are modified for absorption, you would look for a slide that shows a single layer of epithelium lining the cavity. The cells would be cuboidal or columnar in shape and probably have a microvillous surface to increase surface area. Since the esophagus receives undigested food, it would have a stratified epithelium consisting of squamous cells to protect it against damage.

69. Step 1: Check for striations. (If striations are present, the choices are skeletal muscle or cardiac muscle. If striations are absent, the tissue is smooth muscle.) Step 2: Check for the presence of intercalated discs. (If the discs are present, the tissue is cardiac muscle. If they are absent, the tissue is skeletal muscle.)

❑ Media Lab Instructor Notes

Web addresses often change. To avoid dead links, we are listing the keywords in parentheses next the to Web Explorations. Simply go to the Companion Website (http://www.prenhall.com/martini), then select the Fifth Edition of Fundamentals of Anatomy and Physiology and search using the key word to locate the current address.

Animations (Website)

- Figure 4-2—Animation in zoom in format. Demonstrating cell to cell junctions; suitable for lecture enhancement or self study during epithelial discussion
- Figure 4-6—Animation in play /pause format. Merocrine and holocrine secretion animation; suitable for lecture enhancement explanation of difference between merocrine and holocrine glands.
- Figure 4-16—image with pop-up labels. Membranes of the body; suitable for lecture enhancement when classifying membranes in the body or student self-study.

Web Explorations (Overview)
Web Exploration 1 (**CONNECTIVE TISSUE**)

- *Goal*—review / self check learning of connective tissue
- *Description of page*—MCAT study aid for histology, short prose with quiz application available at top right corner
- *Expectations of student behavior*—read first page, click on quiz button and test knowledge
- *Instructor's role*—introduce connective tissue, give site and perhaps award credit for student usage
- *Special notes or further uses of exploration*—good for self study; students can bookmark for study / review of other topics available in "Index" on top right

Web Exploration 2 (**HISTOLOGY**)

- *Goal*—observational skills, comparative observations
- *Description of page*—five linked pages with short prose and good images demonstrating tissue characteristics
- *Expectations of student behavior*—read information, click on images back to start page
- *Instructor's role*—introduce histology, four tissue types, microscopy and observational skills
- *Special notes or further uses of exploration*—help students navigate from images back to prose (use navigator "back" button or "go back" on top of each page)

Additional Web Explorations
Should the two explorations found in the text not answer your needs, a third exploration is provided below. Your students do not have direct access to this exploration. You must provide them the address and information in the following paragraph.

Web Exploration 3
Estimated time for completion = 10 minutes

How important is connective tissue to the overall health of the body? Marfan's Syndrome is a heritable connective tissue disorder. In this disease, the connective tissue grows slowly and the matrix formed is more brittle. Try to imagine how this disease would affect the body. Make a list of those organs and systems that you expect would be adversely affected. Go to this Website (http://www.marfan.org/pub/factsheet.html) and read the material presented by the National Marfan Foundation. Go back to your original list and revise it to include any new information you have learned.

Web Exploration 3 (**MARFAN**)

- *Goal*—critical thinking, information synthesis (connective tissue)
- *Description of page*—National Marfan Foundation information page – organization information
- *Expectations of student behavior*—read information and write observations
- *Instructor's role*—clear explanation of connective tissue, homeostasis, and DNA; question clarification concerning research and DNA portion of the page
- *Special notes or further uses of exploration*—can return to site to help explain genetic counseling, genetic research

	Topic Outline			A/V Resources				
Objectives	**Chapter 4** **The Tissue Level of Organization** (page 1 of 4)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	I. Introduction		1a, 4ab, 5a					
	II. Epithelial Tissue							
1a	A. Functions of Epithelial Tissue	4-1		●	●			
1b	B Specializations of Epithelial Cells							
	C. Maintaining The Integrity of Epithelia	4-2abcd	1c, 5b	●	●	●		
	1. Intercellular Connections	4-2e		●	●			
	2. Attachment to the Basement Membrane		2a					
	3. Epithelial Maintenance and Repair		2cd, 5c					
	D. Classification of Epithelia		2b					
	1. Squamous Epithelia	4-3		●	●			●
	2. Cuboidal Epithelia	4-4		●	●			●
	3. Columnar Epithelia	4-5		●	●			●
	E. Glandular Epithelia		1d					
	1. Endocrine Glands							

TOPIC OUTLINE				A/V RESOURCES				
Objectives	**Chapter 4** **The Tissue Level of Organization** (page 2 of 4)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	2. Exocrine Glands	4-6,7		●	●	●		
1c	**III. Connective Tissues**		5d					
2a	A. Classification of Connective Tissues	4-8	4c	●	●			
	B. Connective Tissue Proper	4-9		●	●			
	1. The Cell Populaton							
	2. Connective Tissue Fibers		3a					
	3. Ground Substance	4-9		●	●			
	4. Embryonic Connective Tissues	4-10			●			
	5. Loose Connective Tissues	4-9,10b,11a		●	●			
	6. Dense Connective Tissues	4-12		●	●			
	C. Fluid Connective Tissues	4-13		●	●			
	D. Supporting Connective Tissues							
	1. Cartilage	4-13a,14a,15	2e	●	●			
	2. Bone	4-16	2f	●	●			

Topic Outline				A/V Resources				
Objectives	**Chapter 4** **The Tissue Level of Organization** (page 3 of 4)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
2b	**IV. Membranes**							
	A. Mucous Membranes	4-17a	1b	●	●	●		●
	B. Serous Membranes	4-17b		●	●	●		●
	C. The Cutaneous Membrane	4-17c		●	●	●		●
	D. Synovial Membrandes	4-17d		●	●	●		●
1d	**V. The Connective Tissue Framework of the Body**	4-18		●				
	VI. Muscle Tissue		2g, 5e					
	A. Skeletal Muscle Tissue	4-19a		●	●			
	B. Cardiac Muscle Tissue	4-19b		●	●			
	C. Smooth Muscle Tissue	4-19c		●	●			
1e	**VII. Neural Tissue**	4-20	2h, 5f	●	●			
	VIII. Tissue Injuries and Aging							
	A. Inflamation and Regeneration							
	1. First Phase: Inflammation	4-21		●	●			

Topic Outline				A/V Resources				
Objectives	**Chapter 4** **The Tissue Level of Organization** (page 4 of 4)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	2. Second Phase: Regeneration							
	B. Aging and Tissue Repair							
1f	C. Aging and Cancer Incidence							

CHAPTER 5

The Integumentary System

Introduction

Students and (I suspect) most instructors do not think of the skin as an interesting organ compared to the heart or the brain. However, on a day to day basis, we are much more concerned with our skin than with any other organ. This does not just include cosmetics and worries about wrinkles. Our culture's near obsession with tanning has produced an epidemic of skin cancer. The incidence of skin cancer has increased by over 800% in the last 50 years. This makes it the fastest growing form of cancer. Most skin cancers are easily operable. Of the several forms of skin cancer, one is particularly devastating. Basal cell carcinomas are fatal in the majority of cases. It is now widely accepted that the primary cause of these cancers is UV rays in sunlight. The mechanisms by which UV light causes cancer are interesting. In particular, there is evidence that one of the main ways UV leads to cancer is by suppression of the cancer destroying cells in the skin. For more details on this, and on numerous other interesting aspects of the biology of the skin, see Marc Lappe's book *The Body's Edge* (1996, Henry Holt and Company).

Instructional Goals/Learning Objectives

1. To familiarize students with the basic structural and functional characteristics of the integument.

   a. Describe the main structural features of the epidermis and explain their functional significance.
   b. Explain the basis for individual and racial differences in skin color.
   c. Discuss the effects of ultraviolet radiation on the skin and the role played by melanocytes.
   d. Describe the structure and functions of the dermis.
   e. Explain the mechanisms that produce hair and that determine hair texture and color.
   f. Discuss the various kinds of glands found in the skin, and what secretions they produce.
   g. Explain how the sweat glands of the integumentary system play a major role in regulating body temperature.
   h. Describe the anatomical structure of nails and how they are formed.
   i. Explain how the skin responds to injury and repairs itself.
   j. Summarize the effects of aging on the skin.

❑ Teaching Strategies

1. Analogies

a. As a way of illustrating that the cells of the epidermis originate primarily from the stratum germinativum and are pushed to the surface; imagine holding a deck of cards. You place one card down on the table (the basement membrane). You place the second card under the first, then the third card under the second, the fourth card under the third, etc. Eventually, all 52 cards are stacked on the table, but the first card, the "oldest" card, is on the top of the deck.

b. If you could peel the epidermal layer off, the papillary layer of the dermis would resemble hundreds of egg cartons lined up next to one another.

c. Scar tissue can fill-in as stroma, but it cannot be functional, or parenchymal. Wood putty can fill in a hole, but it does not look like or function like real wood.

2. Demonstrations

a. At the risk of "grossing them out," bring in a piece of chicken and show the students how the skin is attached to the underlying muscle as an example of the subcutaneous layer, or hypodermis.

3. Vocabulary Aids

a. Compare the word stratum to the already familiar word stratified, and indicate that the root "strata" means "layered."

b. As in Chapter 4, associate the word germinativum with germinate to emphasize that these are cells that grow, like seeds that can be germinated.

c. Merkel cells are neurological in their function; the word Merkel rhymes with Erkel, a TV sit-com character that easily gets on one's nerves.

d. The cells of the stratum spinosum get their name because of their "spiny" appearance, but one could also think of them as the layer that "spins" off of the germinativum.

e. The keratohyalin granules within the cells of the stratum granulosum give them a "grainy" appearance.

f. The keratin of the stratum corneum makes it as tough as a rhino's horn (gives a whole new meaning to the word "horny").

g. Nicotine patches and sea sick patches are examples of transdermal medication delivery systems.

h. In order to learn the individual receptors and what they do, make the following associations:

1. Midas Touch - Meissner's corpuscles (for light touch)
2. A ruffle can be stretched - Ruffini corpuscles (for stretch)
3. The "P" in pressure - Pacinian corpuscles

i. Associate the word vellus with velvet.

4. Applications

a. Psoriasis results from an increase in the mitotic rate of the germinativum causing the epidermal layer to be replaced within a week instead of the normal 2-4 weeks.

b. After a long bath, our fingers resemble prunes because of the swelling that occurs during the hypotonic osmotic flow of water into our cells, and the subsequent reabsorption of that water. It takes a while for our cells to return to their original shape after they "deflate."

c. Ironically, the "tan" that we find so attractive is caused by the melanocytes responding to the damage done by the UV rays of the sun. This damage can result in tumors in the basal cells (basal cell carcinoma), the upper epidermal cells (squamal cell carcinoma), or in the melanocytes (melanoma). Since the basal cells and squamous cells are part of the epidermis, if caught early enough, they can be removed. But the melanocytes are situated so closely to the dermal layer that if they become malignant, they can easily metastasize to the blood and lymph vessels of the connective tissue. Consequently, basal and squamal cell carcinomas are rarely fatal, but malignant melanoma can be fatal.

d. Dermabrasion is a process that removes the upper layers of the epidermis in order to stimulate growth and repair of disfigured or scarred skin. The dermatologist must be extremely careful not to sand down deeper than the stratum germinativum or epidermal derivatives, otherwise, the resulting new tissue will come from the dermal layer and appear as scar tissue.

e. A birthmark can refer to a variety of pigmentation patterns, but it usually is a result of a concentration of blood vessels known as a hemangioma. Old Wives' Tales attempt to relate the occurrence of a birthmark with an event that happened during pregnancy. "Strawberry marks" (capillary hemangiomas) often disappear, but "port wine stains" or "stork bites" (cavernous hemangiomas), commonly seen on the forehead or neck, are much larger and may be permanent.

f. In spite of what commercials for hair products may lead you to believe, the hair shaft itself is dead; it cannot be made more "healthy" once it has been formed. However, our hair grows in cycles that alternate between a growth period, when the follicle is active, and a dormant period, when the follicle remains inactive and the hair is shed. The composition of the hair can be influenced by changing physiological factors that may affect the active cells of the follicle. Sometimes, bodies will be exhumed, even

years alter death, for the purpose of a forensic examination of the hair to see if there is evidence of poisoning.

g. If an injury involves a first- or second-degree burn, elements of the epidermis and dermis remain to replace the destroyed cells. If an injury involves a third-degree burn, there is no integumentary tissue left for mitotic replacement, so grafts must be used to repair the damage.

5. Common Student Misconceptions/Problems

a. Students tend to limit recognition of the integumentary system to the epidermal layer. Point out that often times the terms "skin" and "integument" are used interchangeably, but the skin is really composed of all four histological features, and thus is classified as an organ. This organ interacts with numerous other structural organs, thus skin and its derivatives are collectively called the integumentary system.

b. For some reason, there is a tendency to confuse keratinocytes and keratin with melanocytes and melanin. Emphasize that the former are the predominant cell-type that make up the epidermis and produce a scleroprotein that contributes to the structure of the epidermis, hair, nails, and tooth enamel, anywhere there needs to be a hard, impenetrable, water resistant surface. The latter are specialized cells that are located at the stratum germinativum and produce a pigment that contributes to the color of skin. Granules of melanin developing the melanocytes but then migrate through the layers of the epidermis and become incorporated within the keratinocytes. Imagine the melanocytes at the bottom of the epidermis releasing pigment that moves through the layers of epidermal cells, like bubbles floating up through water. Exposure to the UV rays of the sun, increases the melanin production which increases the percolating action, just like adding heat to a pot of water.

c. Even though cells at the basement membrane appear cuboidal, the entire epidermis is classified as stratified squamous epithelium, because that is the cell type that is the end result of development of the basement cells after they differentiate and mature.

d. Some authors refer to the stratum germinativum as the stratum basale and use germinativum to describe the basale and spinosum collectively. Bringing this variation of terminology to the attention of the students might help to alleviate any confusion should they be reading in other resources. (It also helps to illustrate the importance of the preciseness of the anatomical language.)

e. Students commonly assume that the dermis must give rise to the hair follicles or sweat glands, since that is where they seem to "reside." To dispel this misconception, stress how much thicker the dermis is as compared to the epidermis. Reiterate that the dermis is made up of loose connective tissue, and while some of the accessory organs derived from the epidermis might be located within the dermis, the structures of these derivatives cannot grow from the cells of the dermis, connective tissue cells can only give rise to more connective tissue cells.

6. Lecture ideas

a. Take this opportunity to emphasize each tissue type in an effort to underscore the topics discussed in the previous chapter.

b. Refer to the diagram of the "Embryology Summary: Formation of Tissues" from Chapter 4. Correlate the primary germ layers with the organization of the integument. Explain that the epidermis and dermis arise from different embryological germ layers; hence, the epidermis is stratified squamous epithelium (from ectoderm), while the dermis is loose, irregular connective tissue (from mesoderm). As development continues, there is close infiltration of the two layers. The subcutaneous layer, or hypodermis, is technically not part of the skin, but is also derived from mesoderm and is sometimes classified as a third layer. It is composed of loose connective tissue, usually containing adipose, and binds the skin to the underlying tissue (it corresponds to the superficial fascia).

c. As macrophages, Langerhans cells are capable of initiating an immune response, underscore the "logic" of having these cells located near the surface of our mechanical barrier to external pathogens.

d. Beginning with the cells located in the upper stratum granulosum and continuing up through the corneum, the cells lose their nuclei, and form essentially a "suit of armor." The resulting water-resistant barrier was an important evolutionary development that allowed animals to adapt to dryer land habitats.

e. The stratum corneum varies in thickness depending upon the location of the skin and pressure or friction on the skin.

f. Explain that it is as important to keep body water in as it is to keep environmental water out. The skin has many mechanisms for preventing water movement across it. After explaining the mechanisms, point out that sweating represents a loss of body water, over-riding the water reservation mechanisms to allow for loss of body heat.

g. Though the dermis is composed of two layers, the demarcation where the papillary layer ends and the reticular layer begins is not very distinct. There is a gradual change from loose connective tissue to dense irregular connective tissue as the collagen fibers become more compact.

h. An individual hair follicle is simply an indentation or invagination from the epidermal surface; hence, the cells that line the follicle are stratified squamous epithelial cells.

i. Draw attention to the structure of the sebaceous and sweat glands. As exocrine glands, they possess ducts that lead to either a hair follicle or to the skin's surface.

Answers to End of Chapter Exercises

Level 1: Reviewing Facts and Terms

1. a
2. c
3. d
4. b
5. c
6. a
7. d
8. b
9. b
10. a
11. d
12. b
13. a
14. a

15. Epidermal cell division occurs in the stratum germinativum.

16. The precursors of keratin are keratohyalin and eleidin. Keratohyalin, produced in the stratum granulosum, is the precursor of eleidin which is found in flattened, densely packed cells in the stratum lucidum.

17. Carotene and melanin are the epidermal pigments.

18. EGF promotes the divisions of germinal cells in the stratum germinativum and stratum spinosum. EGF accelerates the production of keratin in differentiating epidermal cells. EGF stimulates epidermal development and epidermal repair after injury. EGF stimulates synthetic activity and secretion by epithelial cells.

19. (1) papillary layer: consists of loose connective tissue, contains the capillaries and sensory neurons (2) reticular layer: consists of dense irregular connective tissue and bundles of collagen fibers. The reticular and papillary layers of the dermis contain networks of blood vessels, lymph vessels and nerve fibers.

20. (1) Internal root sheath-layer which surrounds the root. (2) External root sheath-layer extending from skin surface to hair matrix. (3) Glassy membrane-the thickened basement membrane.

21. (1) apocrine (suderiferous) glands (2) merocrine (eccrine) glands

Level 2: Reviewing Concepts

22. Insensible perspiration is water loss via evaporation through the stratum corneum of the skin. Sensible perspiration is produced by active sweat glands.

23. Substances that are lipid soluble pass through the permeability barrier easily because the barrier is composed primarily of lipids surrounding the epidermal cells. Water-soluble drugs are hydrophobic and thus don't penetrate the permeability barrier easily.

24. A tan is a result of the synthesis of melanin in the skin. Melanin helps prevent skin damage by absorbing ultraviolet radiation before it reaches the deep layers of the epidermis and dermis. Within the epidermal cells, melanin concentrates around the outer wall of the nucleus, so it absorbs the UV light before it can damage the nuclear DNA.

25. Lines of cleavage represent the orientation of the collagen and elastin fibers of the dermis, so oriented as to resist normal stresses on the skin. Cuts along the lines of cleavage are more likely to remain closed, and thus will heal more quickly.

26. Inflammation of the skin is painful because of the abundance of sensory receptors in the skin. Changes associated with swelling stimulate the sensory receptors and bare nerve endings, resulting in a painful sensation.

27. The subcutaneous layer is not highly vascular, and does not contain any major organs, thus the potential for tissue damage is reduced.

28. The cells that produce the nails can be affected by conditions that alter body metabolism, and thus hint at possible disease conditions.

29. Scabs temporarily restore epidermal integrity, restricting further entry of microorganisms.

30. The dermis becomes thinner and the elastic fiber network decreases in size, weakening the integument and causing loss of resilience.

Level 3: Critical Thinking/Clinical Application

31. The child probably has a fondness for vegetables that are high in carotene, like sweet potatoes, squash, and carrots. It is not uncommon for parents to preferentially feed babies what they will eat best. If the child consumes large amounts of carotene, the yellow-orange pigment will be stored in the skin, producing a definite yellow-orange skin color.

32. Most elderly people have poor circulation to the skin. Thus, temperature receptors in the skin do not sense as much warmth as when there is a rich blood supply. The sensory information is relayed back to the brain and the brain interprets this as being cool or cold.

33. (a) Ultraviolet radiation in sunlight converts a cholesterol-related steroid into vitamin D_3, or cholecalciferol. This compound is then converted to calcitriol, which is essential for normal calcium and phosphorus absorption by the small intestine, which are in turn necessary for normal bone maintenance and growth. (b) Milk is routinely fortified with cholecalciferol, usually just identified as "vitamin D," which is easily absorbed by the intestines.

34. Sweating from merocrine glands is precisely regulated, and one influencing factor is emotional state. Presumably, when willfully lying, a person will feel nervous and sweat more noticeably, and this sweating can be measured by the lie detector machine.

❑ Media Lab Instructor Notes

Web addresses often change. To avoid dead links, we are listing the keywords in parentheses next the to Web Explorations. Simply go to the Companion Website (http://www.prenhall.com/martini), then select the Fifth Edition of Fundamentals of Anatomy and Physiology and search using the key word to locate the current address.

Media Resources on the Student's CD-ROM and Companion Website

Animations (Website)

- Figure 5-1—Animation in zoom in format. Skin anatomy; suitable for lecture enhancement while discussing skin anatomy or self study tool for students
- Figure 5-4—Animation in play/pause format. Melanocyte melanin production; suitable for quick lecture enhancement of melanin protection or student self-study.
- Figure 5-11—Animation in play/next format. Integumentary repair; suitable for lecture enhancement during wound repair discussion.

Web Explorations (Overview)
Web exploration 1 (**MELANOMA**)

- *Goal*—critical thinking, subject understanding motivation
- *Description of page*—skin cancer foundation informational page, links to other foundation information pages
- *Expectations of student behavior*—read pages, navigate through five sections, reflect on personal sun exposure
- *Instructor's role*—introduce melanoma, warn students of images in the Early Warning System section
- *Special notes or further uses of exploration*—much more information on squamous cell carcinoma and basal cell carcinoma accessible via home page.

Web exploration 2 (**ACNE**)

- *Goal*—critical thinking, spatial learning
- *Description of page*—article on acne from *Healthline* magazine; left side bar has clickable links
- *Expectations of student behavior*—read information, return to textbook for image and clarification
- *Instructor's role*—introduce integumentary system anatomy, assist in building spatial associations
- *Special notes or further uses of exploration*—can bookmark site for reference during respiratory system or personal use. Easy to read articles on many health issues.

Additional Web Explorations

Should the two explorations found in the text not answer your needs, a third exploration is provided below. Your students do not have direct access to this exploration. You must provide them the address and information in the following paragraph.

<u>Web Exploration 3</u>
Estimated time for completion = 10 minutes

Male pattern baldness is a fact of life for many men. What causes this to occur? Can it effect females as well? Why does Rogaine seem to work for some men and not others? To answer these questions, read the information provided by at this Website (http://www.follicle.com/types_androgenetic.html). After reading the information given and coming up with answers to the questions posed above, think about how the American popular culture treats male pattern baldness. Discuss your thoughts with your classmates, using the communication avenues available on the Companion Website.

<u>Web exploration 3</u> **(PATTERN BALDNESS)**

- *Goal*—critical thinking, information synthesis (pattern baldness)
- *Description of page*—Alopecia informational page, sponsored by Pharmacia Geoff
- *Expectations of student behavior*—read information and write observations
- *Instructor's role*—explanation of terminology in article (alopecia, androgenetic, dihydroxytestosterone, etc.), media examples of American popular culture treatment of bald men / women
- *Special notes or further uses of exploration*—left side of page has many distracting links, pharmacology portion may be frustrating for novice students

Topic Outline				A/V Resources				
Objectives	**Chapter 5** **The Integumentary System** (page 1 of 3)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	I. Introduction	5-1	5a, 6ab	●	●	●		
1a	**II. The Epidermis**	5-2	5b	●	●			
	A. Layers of the Epidermis	5-3	1a, 3a, 5c	●	●			●
	1. Stratum Germinativum	5-2a, 3	5d, 3bc	●	●			●
	2. Stratum Spinosum	5-3	3d, 6c	●	●			●
	3. Stratum Granulosum	5-3	33, 6d	●	●			●
	4. Stratum Lucidum	5-3		●	●			●
	5. Stratum Corneum	5-3	3fg, 4ab, 6ef	●	●			●
1b	B. Skin Color		4c					
1c	1. Epidermal Pigmentation	5-4		●	●	●		
	2. Dermal Circulation							
	C. The Epidermis and Vitamin D_3							
	D. Epidermal Growth Factor							
1d	**III. The Dermis**		4d, 5e					

Objectives	TOPIC OUTLINE **Chapter 5** **The Integumentary System** (page 2 of 3)	Figures	Strategies	A/V RESOURCES Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	A. Dermal Organization	5-1,2a	1b, 6g	●	●			
	1. Wrinkles and Stretch Marks							
	2. Lines of Cleavage	5-5		●	●			
	B. Dermal Circulation and Innervation							
	1. The Dermal Blood Supply		4e					
	2. The Innervation of the Skin	5-1	3b	●	●			
	IV. The Subcutaneous Layer	5-1	2a	●	●			
	V. Accessory Structures							
1e	A. Hair Follicles and Hair							
	1. Hair Structure	5-1,6,7		●	●			
	2. Types of Hairs		3i					
	3. Hair Color							
	4. Functions of Hair	5-7a		●	●			
	5. Hair Production and Follicle Structure	5-7	6h	●	●			

Objectives	Topic Outline: **Chapter 5 The Integumentary System** (page 3 of 3)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	6. Growth and Replacement of Hair		4f					
1f	B. Glands in the Skin		6i	●	●			
	1. Sebaceous (Oil) Glands	5-8		●	●			
1g	2. Sweat Glands	5-9						
	3. Other Integumentary Glands							
	4. Control of Glandular Secretions							
1h	C. Nails	5-10		●	●			
	VI. Local Control of Integumentary Function							
1i	A. Injury and Repair	5-11	1c, 4g	●	●	●		
1f	**VII. Aging and the Integumentary System**							
	VIII. Integration with Other Systems	5-12			●			

CHAPTER 6

Osseous Tissue and Skeletal Structure

❑ Introduction

Osteoporosis is a good example application of the material in this chapter. You might begin by showing some data on prevalence of osteoporosis and an image of an advanced case for dramatic effect. The students readily identify with this disease since many of them have grandparents who are afflicted. Also many of the female students have a genuine concern about what they can do to avoid this disease. A discussion of the role of estrogen in osteoporosis is a good example of the need to integrate information from multiple organ systems to understand disease. The students also appreciate a discussion of some of the current therapies and ideas for prevention. Some of this is discussed in a recent book by Ricklefs and Finch entitled *Aging* (Scientific American Library, 1995).

❑ Instructional Goals/Learning Objectives

1. To reinforce the mental link between structure and function at the microscopic and macroscopic levels.

   a. *Describe the functions of the skeletal system.*
   b. *Identify the cell types found in bone and list their major functions.*
   c. *Compare the structures and functions of compact and spongy bone.*
   d. *Compare the mechanisms of intramembranous and endochondral ossification.*
   e. *Discuss the timing of bone development and growth, and account for the differences in the internal structure of adult bones.*
   f. *Classify bones according to their shapes and give examples of each type.*

2. To provide a detailed example of a negative feedback control mechanism, the hormonal regulation of calcium ion concentrations. To remind students that homeostasis represents a dynamic equilibrium among gains, turnover, and losses, and to note how the regulatory hormones affect the individual factors to produce coordinated effects.

   a. *Describe the remodeling and homeostatic mechanisms of the skeletal system.*
   b. *Discuss the effects of nutrition, hormones, exercise, and aging on bone development and the skeletal system.*
   c. *Describe the different types of fractures and explain how they heal.*

❑ Teaching Strategies

1. Analogies

a. It might be helpful to compare the bones to the integument or the blood cells as examples of how things can change while appearing to stay the same. In both cases, cells have a very short life span, which means dead cells are continually being replaced by new cells. The homeostatic control of this turnover is so balanced, that the perception is that our skin remains the same or our blood cell population is invariable. As an individual interested in health care, you know how important it is to maintain a balanced diet, and so you keep a supply of the most important food group: chocolate. Since you eat so much chocolate (you are very healthy), you keep two dozen candy bars in your desk drawer, you know how dangerous it would be if your supply was to run out (after all, what if the stores are closed, or you have to stay up all night to write a paper or study for an anatomy and physiology exam). You decide to guard against this panic-initiating possibility by taking inventory once a day and never letting your supply dwindle down below 18 candy bars. As soon as your stash begins to approach that number, your homeostatic regulatory mechanism kicks in, you purchase more chocolate, and you store it in its proper place until needed. You are comforted by the thought that, whether you have as few as 18 candy bars or as many as 24, the perception is that you will always have a drawerful!

b. Without the support that our skeleton provides, we would resemble lumpy water balloons.

c. Suppose you were an engineer, and you were commissioned to design a bone. Functionally, bones need to be strong enough to protect organs and support weight. A solid, cylindrical shape would achieve this function, but then they would be too heavy for us to comfortably move. We also need to find some place for storage of nutrients and production of blood cells; a solid structure would not allow for these functions. If we made the cylinder hollow, like a pipe, that would provide the space for storage and production, but it still might be too heavy. Suppose the walls of the pipe were made of a compact, but porous material, and to provide extra support, the ends were reinforced with a honey-comb kind of material?

d. Each osteon has the appearance of a cross-section through a tree trunk.

e. Indicate that if drawn out of context, an osteocyte looks like an octopus with many arms. The arms of the osteocyte in one room (lacuna) must reach through holes in the wall (the canaliculi within the lamellae) to hold hands with the osteocytes located in neighboring rooms. By linking hand-in-hand, the osteocytes form a cellular chain of communication from the canal, where the blood vessels are located to the outermost layers of the Haversian System.

f. To visualize the difference between intramembranous ossification and endochondral ossification, use the following analogy. If you wanted to sculpt something out of clay, you could approach it in one of two ways. One approach would be to start with a core and add to that core, shaping it as you added clay, until it was the size and shape you

desired. Another approach would be to first make a hollow mold of the shape you were looking for, and then fill in the mold.

g. Have students act out the following analogy for endochondral ossification. It will help them visualize the processes of bone growth. (They can use sheets of paper for the bricks.) Imagine two masons standing face-to-face in the middle of a field. They are separated by a course of loose bricks between them, three bricks thick. One mason (the "Cementer") begins to cement together the row of bricks on his side. As he cements, the other mason (the "Adder") adds a new row of loose bricks to his side. They work at the same rate, advancing row-by-row, one cementing, one adding. Eventually the cement wall would grow longer and longer, and the masons would begin to move away from the spot where they started; but they would always remain separated by three rows of loose bricks (unless the Adder stops adding bricks).

h. As an analogy for increasing the diameter of a developing bone, continue the analogy from above. Now imagine the same pair of masons are joined by a second pair, positioned so that one of the new masons is back-to-back with a mason in the original pair. Each face-to-face pair has a course of bricks between them, three bricks thick, just as before. The outside masons are Adders, but this time the inside masons are Removers. The Adders begin to add a row of bricks on their side of the wall; but as they do, the Removers remove a row on their side. They work at the same rate, advancing row-by-row, the Adders adding and the Removers removing. As each pair advances, the two Removers in the center begin to move apart, creating an ever-increasing distance between them; but the wall will never be more than three bricks thick.

2. Demonstrations

a. A dramatic demonstration can be performed to illustrate the weight-bearing properties of a cylinder. You will need a piece of typing paper, a paper plate, some tape, a scissors, and a large, heavy rock. Ask the students if they every played the childhood game of "Scissors, Paper, Rock," and remind them that in the game scissors cut paper, paper wraps rock, and rock breaks scissors. While holding the piece of paper on its edge, announce that you are going to prove that paper is stronger than either scissors or rock by balancing both on the paper's edge. Roll the paper, and tape the short edges together, so that you form a cylinder. Stand the cylinder on the table, and place the paper plate on top. Now place the scissors and rock on the plate. Voila!

3. Vocabulary Aids

a. With the introduction of the term osteoblast, explain that the suffix "blast" means "precursor" and usually refers to an immature stage in cellular development.

b. Suggest that they associate the alliteration in the word "blast" with the word "build" as a way of remembering that osteoblasts build bone.

c. Indicate that progenitor cells are "first" (pro) "generation" cells that "generate" (genitor) osteoblasts. (Imagine a sequel to the movie "Terminator" called "Genitor.")

d. Stress the distinction between osteoblasts and osteoclasts. Indicate that the suffix "clast" means "to separate" or "to break apart."

e. Associate the layers of the lamellae with a layer of plastic used to "laminate."

f. The term trabecula literally means a "little beam" and is used to describe a network of interconnecting bridges of tissue.

g. Bone terms:

Ramus-convert ram to arm
Trochanter-large and knobby, like a "rock" (roch)
Tuberosity-not as large as trochanter, sticks out like a "but" (tub backwards)
Tubercle-a littler "but"
Condyle-usually paired with a fossa or sulcus
Trochlea-pulley-shaped
Sulcus-sunken
Foramen-You walk through an "opening"
Meatus-that leads down a "hall,"
Sinus-You enter a "room,"
Fissure-with a "crack" in the wall.

4. Applications

a. Everyone grows up learning that "calcium builds strong bones," but Ca^{++} ions are needed for many other physiological processes, such as muscle contraction, nerve impulse conduction, blood clotting, and membrane transport systems. We rely on dietary intake to replenish our calcium supplies; that calcium is stored in the bone.

b. The bone age of a child can be determined by examining radiographs that show the size of the epiphyseal plate.

c. Astronauts must perform weight-bearing exercises during flight to compensate for the loss of bone mass caused by long term exposure to zero gravity (weightlessness).

5. Common Student Misconceptions/Problems

a. A difficult concept to visualize, and yet very important to comprehend, is that bones are continually being remodeled. Students do not understand this phenomenon. After all, in their perception, bones do not change shape, muscle attachments stay constant, our structural form created by our skeleton remains the same. The challenge will be to persuade them that besides giving us support and leverage, our bones act as a reservoir for calcium salts, a well that can be dipped into and replenished as needed. Stress that the phenomenon of remodeling occurs at a molecular level.

b. Point out that adipose tissue is not the only tissue that stores lipids, it is also stored in bone.

c. We attribute movement to muscle activity, but without bones to act as levers, muscles could not achieve directed movement.

d. Students commonly confuse the Haversian canal of the osteon with the medullary canal. Underscore the relative size of the osteon as it sits within the compact bone. Referring to Figure 6-1, stress that the osteon is a microscopic component of the compact bone and has nothing to do with the medullary canal.

e. Distinguish among the often confusing terms osteogenesis, ossification, and calcification: "The process of calcification (a generic term for deposition of calcium) during ossification (conversion to bone) is called osteogenesis (bone development)."

f. Distinguish between gigantism and acromegaly.

6. Lecture ideas

a. When describing the role of PTH and Calcitonin in the control of blood calcium, diagram the homeostatic balance on the board. Make sure to correlate the structures involved to the components of the homeostatic pathways that were described in Chapter 1. Include the negative feedback link:

(stimulus)$\Rightarrow$	RECEPTOR$\Rightarrow$	CONTROL$\Rightarrow$ CENTER	EFFECTOR$\Rightarrow$	(response)
$\downarrow Ca^{++}\Rightarrow$	CHEMORECEPTOR$\Rightarrow$ CELLS OF PARATHYROID	PARATHYROID RELEASES PTH	$\Rightarrow$BONE $\Rightarrow$ OSTEOCLASTS & KIDNEY REABSORB Ca^{++}	$\uparrow Ca^{++}$
$\uparrow Ca^{++}\Rightarrow$	CHEMORECEPTOR$\Rightarrow$ CELLS OF THYROID	THYROID$\Rightarrow$ RELEASES CALCITONIN	BONE$\Rightarrow$ OSTEOBLASTS & KIDNEY RELEASE Ca^{++}	$\downarrow Ca^{++}$

Answers to End of Chapter Exercises

Level 1: Reviewing Facts and Terms

1.	b	6.	b
2.	a	7.	b
3.	a	8.	c
4.	c	9.	a
5.	d	10.	d

11. (1) support (2) storage of minerals and lipids (3) blood cell production (4) protection (5) leverage

12. (1) osteocytes (2) osteoblasts (3) osteoclasts (4) osteoprogenitor cells

13. Osteoblasts are responsible for the production of new bone (osteogenesis). Osteoclasts contain lysosomes that secrete enzymes and acids, which dissolve the bony matrix and release the stored minerals of calcium and phosphate (osteolysis).

14. (1) isolates the bone from surrounding tissues (2) provides a route for circulatory and nervous supply (3) actively participates in bone growth and repair

15. In intramembranous ossification, bone develops from mesenchyme or fibrous connective tissue. In endochondral ossification, bone develops from a cartilage model.

16. (1) the nutrient artery and vein (2) metaphyseal vessels (3) periosteal vessels

17. (a) calcium and phosphate salts, vitamins A, C, D_3 (b) calcitriol, growth hormone (GH), thyroxine, estrogens in the female and androgens in the male, calcitonin, parathyroid hormone.

18. (1) the bones (2) the intestinal tract (3) the kidneys

19. stimulates osteoclast activity; increases the rate of intestinal absorption; decreases the rate of excretion of calcium ions

20. inhibits osteoclast activity; decreases the rate of calcium absorption; increases the rate of excretion of calcium ions

Level 2: Reviewing Concepts

21. Nutrients reach the osteocytes by diffusion along canaliculi that open onto the surface of the trabeculae.

22. The osteons are parallel to the long axis of the shaft, which does not bend when forces are applied to either end. Stresses or impacts to the side of the shaft can lead to a fracture.

23. The removal of calcium salts due to inactivity in unstressed bones causes a loss of up to one third of bone mass, causing the bones to become thin and brittle.

24. The digestive and urinary systems (kidneys) play important roles in providing the calcium and phosphate minerals needed for bone growth. In return, the skeleton provides protection and represents a reserve of calcium, phosphate, and other minerals that can compensate for changes in the dietary supplies of these ions.

25. The chondrocytes of the epiphyseal cartilage enlarge and divide, increasing the thickness of the cartilage. On the shaft side, the chondrocytes become ossified, "chasing" the expanding epiphyseal cartilage away from the shaft.

26. At puberty, the epiphyseal cartilages gets narrower and narrower until they virtually disappear, due to the stimulation of ossification by the sex steroids.

27. The thyroid gland secretes calcitonin, which stimulates calcium excretion and inhibits calcium absorption and osteoclast activity. Without calcitonin, blood calcium levels may become abnormally high.

28. When a bone fracture is repaired, the bone is usually stronger and thicker than normal at the fracture site.

29. People get shorter with age due in part to loss of bone density in the vertebrae.

30. Bone markings give clues as to the size, weight, gender, and general appearance of an individual.

31. Elevations and projections on bones are sites of attachment for tendons and ligaments.

Level 3: Critical Thinking/Clinical Application

32. The fracture might have damaged the epiphyseal cartilage. Even though the bone healed properly, the damaged leg did not produce as much cartilage as the undamaged leg. The result would be a shorter bone on the side of the injury.

33. Ossification may begin in the fetus as early as 6 weeks. By 8-10 weeks, the process is well under way and requires large amounts of calcium and phosphate to make the new bone. If the mother's diet does not supply sufficient amounts of calcium for the fetus, then hormonal action will cause minerals to be taken from the mother's bones for use by her fetus. Because Sherry has a diet deficient in calcium, the demineralization of her bone is supplying the calcium needs of her fetus. As a result, Sherry has weak bones that are more likely to fracture.

34. A person suffering from vitamin D_3 deficiency would not be able to absorb calcium effectively from the digestive tract, leading to a shortage of calcium in the blood. In order to maintain homeostasis, the decrease in blood calcium would trigger the release of parathyroid hormone, PTH. The PTH in turn would stimulate osteoclasts to release enough calcium from the bone to maintain proper calcium levels in the blood. Levels of calcitonin would probably decrease, since this hormone lowers blood calcium levels and would aggravate the situation caused by the vitamin D_3 deficiency.

35. In kidney failure, the kidneys are not able to retrieve important ions that have been filtered from the blood, including calcium. This would result in a net loss of calcium from the body and a decrease in the blood levels of calcium. The lower levels of calcium in the blood would trigger higher levels of PTH, which, in turn, would trigger increased release of minerals from bone by the osteoclasts. Over time this would result in demineralized bones similar to those found in individuals with the disease osteoporosis.

❑ Media Lab Instructor Notes

Web addresses often change. To avoid dead links, we are listing the keywords in parentheses next the to Web Explorations. Simply go to the Companion Website (http://www.prenhall.com/martini), then select the Fifth Edition of Fundamentals of Anatomy and Physiology and search using the key word to locate the current address.

Web addresses often change. To avoid dead links, we are listing the keywords in parentheses next the to Web Explorations. Simply go to the Companion Website (http://www.pernhall.com/martini) and search using the key word to locate the current address.

Animations (Website)

- Figure 6-5—Animation with pop-up labels. Lamellar organization in a long bone; suitable for enhancing lecture discussion of long bone structure or self-study.
- Figure 6-8—Animation in play/next format. Endochonral ossification; suitable for lecture enhancement during bone formation.
- Figure 6-10—Animation in play/next format. Appositional bone growth: suitable for lecture enhancement during remodeling discussion.

Web Explorations (Overview)
Web Exploration 1 **(REMODELING)**

- *Goal*—further investigation, relevance of information
- *Description of page*—scientific article from November 1996 edition of The Southern Medical Journal
- *Expectations of student behavior*—read article, focusing on conclusions as they relate to healthy bone
- *Instructor's role*—assist in understanding the more technical portions of the article, guide students through with flow chart of experiment
- *Special notes or further uses of exploration*—well written paper with good documentation and references; good model for writing assignment; only one link to SMJ table of contents.

Web Exploration 2 **(ASBMR, BROCCOLI)**

- *Goal*—critical thinking, applications of knowledge
- *Description of page*—ASBMR news release, short scientifically sound article
- *Expectations of student behavior*—read information, take notes, move to second article and take notes

- *Instructor's role*—assist students in understanding article, relate information to familiar situation
- *Special notes or further uses of exploration*—side bar on left links to many facets of ASBMR, mostly not relevant; difficult to return to requested page on screen (back button)

Additional Web Explorations
Should the two explorations found in the text not answer your needs, a third exploration is provided below. Your students do not have direct access to this exploration. You must provide them the address and information in the following paragraph.

Web Exploration 3
Estimated time for completion = 10 minutes

You have covered the integumentary and skeletal systems and are about to begin the muscular system. In the first chapter you were introduced to the concept of homeostasis. You can now begin to put the systems you have investigated into a homeostatic network, looking at the interactions between them.
Go to this Website (http://www.nurseminerva.co.uk/homeosta.htm#q3) and read the article entitled "How do the skeletal, muscle and integumentary systems interact to preserve homeostasis in the human body?" After completing this article, create a concept map of the integration between these three systems. If you wish, share your ideas with your peers through creating a poster, or by using the communications applications available on the Companion Website.

Web Exploration 3 (**HOMEOSTASIS**)

- *Goal*—critical thinking, concept integration (homeostasis between skeletal, muscular and integumentary systems)
- *Description of page*—three questions on homeostasis answered for nursing students created and maintained by nurses in the UK
- *Expectations of student behavior*—read information, think through relationships and illustrate them
- *Instructor's role*—explanation of terminology, discussion of visualization techniques (concept maps)
- *Special notes or further uses of exploration*—this is a good resource for future information. Class questions can be posed there and answers will be returned within 2 weeks.

Topic Outline				A/V Resources				
Objectives	**Chapter 6 The Osseous Tissue and Skeletal Structure** (page 1 of 2)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
1a	**I. Introduction**	6-1	1ab, 4a, 5abc	●	●			
1f	**II. A Classification of Bones**	6-1	3g	●	●			
	A. Bone Shapes	6-2		●	●			●
	B. Bone Structure							
1b	**III. Bone Histology**		1c, 2a, 3abcd					
	A. The Matrix of Bone							
	B. Cells in Bone	6-3		●	●			
1c	C. Compact Bone and Spongy Bone							
	1. Compact Bone	6-3c,4ab,5	1de, 3e, 5d	●	●	●		●
	2. Spongy Bone	6-4ac	3f	●	●			●
	D. Periosteum and Endosteum	6-6		●	●			
1e	**IV. Bone Development and Growth**		1f, 5e					
1d	A. Intramembranous Ossification	6-7		●	●			
1d	B. Endochondral Ossification	6-8ab,9	1g	●	●	●		●

Topic Outline				A/V Resources				
Objectives	**Chapter 6** **The Osseous Tissue and Skeletal Structure** (page 2 of 2)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	1. Appositional Growth	6-8,10a		●	●	●		
	C. The Blood and Nerve Supplies	6-11		●	●			
2a	**V. The Dynamic Nature of Bone**							
	A. Effects of Exercise on Bone		4c					
2b	B. Hormonal and Nutritional Effects on Bone		5f					
	C. The Skeleton as a Calcium Reserve	6-12		●	●			
	1. Hormones and Calcium Balance	6-13		●	●			●
2c	D. Fracture Repair	6-14		●	●			
	E. Aging and the Skeletal System	6-16			●			
	VI. Bone Markings (Surface Features)		3g					
	VII. Integration with Other Systems	6-17			●			

CHAPTER 7

The Axial Skeleton

❑ Introduction

One of the unique abilities of humans is language. There are many interesting adaptations in our axial skeleton that allow speech production. An interesting way to approach this is to compare some of these structures between humans and our nearest relatives, the chimpanzees. Attempts to teach chimpanzees to use language are now confined to sign language. It was only recently that we came to realize that the voice box of chimps and all other apes is incapable of making the complex sounds of speech. This approach can be carried into the musculature of the head and neck later as well as into the language centers of the brain when discussing the nervous system. There are two excellent sources of information on this topic. Peter Denes and Elliot Pinson have written a fascinating account entitled *The Speech Chain* (2^{nd} Ed. 1993, W.H. Freeman). McNeill Alexander's book *The Human Machine* (1992, Columbia University Press) has a very readable section (Chapter 14) on human speech production.

❑ Instructional Goals/Learning Objectives

1. To prepare the students for study of the skeleton in the laboratory. Orientation to skeletal anatomy is an important component of this preparation.

2. To introduce the major components of the axial skeleton.

    a. *Identify the bones of the axial skeleton and specify their functions.*
    b. *Identify the bones of the cranium and face, and explain the significance of the markings on the individual bones.*
    c. *Describe the structure of the nasal complex and the functions of the individual bones.*
    d. *Explain the function of the paranasal sinuses.*
    e. *Describe key structural differences in the skulls of infants, children, and adults.*
    f. *Identify and describe the curvatures of the spinal column and their functions.*
    g. *Identify the vertebral regions and describe the distinctive structural and functional characteristics of each vertebral group.*

3. Using specific examples, to show how each articulation represents a compromise between strength and mobility.

    a. *Explain the significance of the articulations between the thoracic vertebrae and ribs, and between the ribs and sternum.*

❑ Teaching Strategies

1. Analogies

a. The ethmoid is one of the most difficult bones to visualize since it is not completely discernible. The frontal section in view c of Figure 7-4 will be helpful. Describe the bone as follows. Imagine the ethmoid as a capital letter 'T'. (Make a 'T' with your hands, as you would if you were signaling time out.) Explain that your vertical hand is analogous to the perpendicular plate of the ethmoid, which is only visible through the nasal cavity. The knuckles of the hand that form the cross bar of the"T" are analogous to the crista galli, which can only be viewed from inside the cranial cavity. The tips of your fingers and your wrist of that same hand represent the lateral masses, which can only be viewed within the orbits. The ethmoidal sinuses give the ethmoid a honey-combed look.

b. The fibrocartilage pad that forms the intervertebral articulation is like a jelly donut: the nucleus pulposus is a semi-liquid cushion in the middle of the fibrous tissue that makes up the annulus fibrosus.

c. Besides pointing out the manner in which the atlas differs from the other vertebrae, mention that it holds up the "globe" of the head, just as Atlas in Greek mythology held up the world. As the atlas' superior articulating surfaces slide on the occipital condyles, the movement allows us to nod "yes." Yes! = At Las(t)! Point out that the articulation of the atlas and the axis permits us to shake our head "no." The world rotates on its axis.

2. Demonstrations

a. Indicate that the petrous portion of the temporal bone houses structures of the middle and inner ear. This can be better visualized if a cotton swab or a pipe cleaner is placed in the external auditory meatus and another one is placed in the internal auditory meatus. Have the students imagine that there is a "hallway" that passes all the way through from one pipe cleaner to the next.

b. Have the student palpate his/her own mastoid process. Associate the word "mastoid" with "massive." When compared to the styloid process, this process is more massive.

c. Demonstrate the position of the cribriform plate in relationship to the nose to emphasize that the olfactory nerves pass through the foramina.

d. Situate a single vertebra from each of the three vertebral regions next to one another so that their features can be compared (include both the atlas and axis from the cervical region). Start by indicating all the similarities among them, and then list the differences that are unique to each region. Let the students practice distinguishing among representative bones from each region (try comparing C_7 to T_1, or T_{12} to L_1 where the differences might be more subtle). Emphasize that the transverse foramina make the cervical vertebrae unique from all other vertebrae, and that they allow the passage of the vertebral arteries and vertebral veins carrying blood to and from the

brain. As the detailed structure of the vertebrae is examined, make sure that the individual vertebrae are assembled to reconstruct the entire vertebral column. In this way, the student will appreciate the manner in which the superior articulating surfaces of one vertebra align with the inferior articulating surfaces of the superior vertebra, and how their junction forms the intervertebral foramina.

3. Vocabulary Aids

a. A simplified method of distinguishing the axial skeleton from the appendicular skeleton is to consider that an axial bone is any bone that contains organs: the skull houses the brain, ears, and eyes; the vertebrae enclose the spinal cord, and the ribs wrap around the heart and lungs.

b. Associate the word "magnum" with the word "magnify" to indicate that this is the large opening to allow passage of the spinal cord.

c. The parietal bones get their name, because they form the wall of the cranium, just as a parietal membrane forms the wall of a cavity.

d. The squamal portion of a bone refers to the flattened or "squashed" region, just as squamal epithelial refers to flattened or squashed cells.

e. Anatomically speaking, a process is a projection or a part that "sticks out." With bones, processes are often named for the bone with which they articulate. Therefore, the zygomatic process of the temporal and the zygomatic process of the maxilla articulate with respective processes of the zygomatic bone.

f. Associate the word "petrous" with "petrified" to emphasize the hardness of the petrous portion of the temporal bone, and its effectiveness in protecting the ear structures.

g. Indicate that "styloid" means long and pointed, like the stylus of a pen.

h. The word element "spheno-" means "wedge-shaped." This bone is "wedged" between the cranial and facial bones. Trace the outline of the bat with wings that the sphenoid resembles. Point out that the sphenoid is visible from several vantage points: the orbit, the lateral surface, and the external and internal inferior views.

i. Hypophysis is another word for the pituitary.

j. The sella turcica ("Turkish saddle") and its associated structures act to completely encase and protect the pituitary gland.

k. Pterygoid means wing-shaped. The pterodactyl was a winged dinosaur that lived during the Mesozoic era.

l. Coronoid comes from the word "corona" which means crown. Imagine this process as the point in a king's crown.

m. The word "mental" pertains to the chin. One can associate the word mental with the image of stroking your chin when you are deep in mental activity.

n. The hyoid bone "hides" behind the mandible.

o. Indicate that a pedicle is a stem-like base. The individual stems that attach leaves to a branch are called "pedicles."

p. The coccyx bone gets its name because it resembles the beak of the cuckoo bird (coccyx = cuckoo in Greek).

q. The parts of the sternum were named after the parts of a Greek dagger: manubrium (handle), body (sometimes called gladiolus, which comes from the same root element as gladiator. The gladiators wore breast plates for protection-like the gladiolus or body of the sternum. It is long and thin like the stalk and leaves of the flower gladiola, and xiphoid process (sword-like).

4. Applications

a. If the perpendicular plate of the ethmoid bone varies from its normal position, the result can be chronic sinus problems, a condition referred to as a deviated septum.

b. The lamina is the portion of the vertebra that is removed during a laminectomy.

c. The xiphoid process is used as a palpable landmark during CPR administration.

5. Common Student Misconceptions/Problems

a. Students often lose the perspective that the cranial bones have an inside and outside surface. For example, they might be surprised to discover that the bone of the forehead that they identified externally as the frontal bone, is the same bone that makes up the roof of the orbits when viewed inside the cranium.

b. There is a tendency to confuse the jugular and carotid foramina. Have the students observe that from a view inside the cranial cavity, the two openings are separated by the petrous portion of the temporal bone, the carotid foramen is anterior to the petrous. If the floor of the cranium is viewed from the external inferior surface, the carotid foramen is still anterior, but because the carotid canal travels laterally and posteriorly, the two foramina sit next to each other, with the styloid process situated laterally.

c. Many students think of the maxilla simply as the bone that holds the upper teeth without realizing that it composes most of the face, including the floor of the orbit and the roof of the mouth. Carefully trace the outline of the maxilla.

6. Lecture ideas

a. The ridges, bumps, notches, and extensions are evidence of the muscle attachment sites on the bones. (Foramina provide places for nerves and blood vessels to pass through the bones).

b. After examining all the bones of the cranium, have the students determine which bones exist in symmetrical pairs and which are single, unpaired bones

c. An excellent visualization exercise is to require the students to name and describe the location of all seven bones that comprise the orbit of the eye.

d. When comparing true ribs to false ribs, indicate that the sequence of structures in the sternal junction of a true rib is *rib* ⇒ *cartilage* ⇒ *sternum*; however, the sequence of structures in the junction of the first three false ribs is *rib*⇒ *cartilage*⇒ *cartilage*⇒ *sternum*. The floating ribs do not connect to the sternum at all.

❑ Answers to End of Chapter Exercises

Level 1: Reviewing Facts and Terms

1. i
2. e
3. l
4. a
5. g
6. j
7. b
8. k
9. d
10. h
11. c
12. f
13. b
14. d
15. a
16. a
17. d
18. c
19. a
20. d
21. a
22. b
23. c
24. a
25. d
26. c
27. (1) Lacrimal bone, (2) nasal bone, (3) maxillary bone, (4) zygomati bone, and (5) mandible.
28. (1) Lambdoidal suture, (2) coronal suture, (3) sagittal suture and (4) squamous suture.
29. The vomer forms a bony nasal septum that separates the right and left nasal cavities and separates the external nares anteriorly in the fleshy portion of the nose.
30. Frontal, sphenoid, ethmoid, and maxillary bones.
31. The hyoid is the only bone in the body that does not articulate with another bone.
32. Because the fontanels are made of fibrous connective tissue, they are quite flexible, and the skull can be distorted without damage. Such distortion normally occurs during delivery and eases the passage of the infant along the birth canal.
33. Cervical (7), Thoracic (12), Lumbar (5), Sacral (1), Coccygeal (1).
34. 1) cervical curve 2) thoracic curve 3) lumbar curve 4) sacral curve
35. 1) It protects the heart, lungs, thymus, and other structures in the thoracic cavity. 2) It serves as an attachment point for muscles involved with respiration, the position of the vertebral column, and movements of the pectoral girdle and upper limb.
36. The upper seven pairs are connected directly to the sternum by the costal cartilages. Ribs 8-12 are called false ribs because they do not attach directly to the sternum.

Level 2: Reviewing Concepts

37. d

38. The petrous portion of the temporal bone encloses the structures of the inner ear. The middle ear is located in the tympanic cavity within the petrous portion. The external auditory canal ends at the tympanic membrane, which leads to the inner ear. Mastoid air cells within the mastoid process are connected to the tympanic cavity.

39. The pituitary gland rests in the sella turcica of the sphenoid bone.

40. Human skulls require less effort by muscles and ligaments to balance the head on the spinal column. The neck muscles and ligamentum nuchae in humans are weak when compared to comparable structures in other animals. Due to the weakness of these muscles and ligaments, the human bony processes and lines of the posterior skull are not as well developed as in other animals. The location of the human foramen magnum facilitates the balancing of the skull above the vertebral column and allows an upright posture. The presence of a cervical curvature allows for support of the weight of the head.

41. The sternum consists of the manubrium, sternal angle, body, and xiphoid process. The body of the sternum is often used as a site for taking red bone marrow samples because of its accessibility. The sternal angle is important clinically because the second rib is found lateral to the sternal angle and can be used as a starting point to count ribs. Counting the ribs is important because they serve as landmarks that are used to locate structures in the thorax. The xiphoid process is used in CPR and is easily broken because its only attachment is superiorly, to the sternum. A broken xiphoid process may cause injury to organs located nearby.

42. The lumbar vertebrae have massive bodies and carry a large amount of weight. The large size of the vertebral bodies, coupled with the fact that they are weight bearing, are factors that contribute to the rupturing of a disc. The cervical vertebrae are rather delicate and have small bodies increasing the possibility of dislocations and fractures in this region rather than other regions of the vertebral column.

43. A "runny" nose is caused by an increase in the mucus draining from the membranes of the nasal cavity. The increased production of mucus is a response to many different kinds of stimuli, including irritants and bacterial or viral infections. Its purpose is to flush out the offending substances or microorganisms from the nasal cavity.

44. Keeping your back straight keeps the weight aligned along the axis of your spinal column, where it can be transferred to your lower limbs. Bending your back would strain the muscles and ligaments of the back, increasing the risk of injury.

Level 3: Critical Thinking/Clinical Application

45. The virus could have been inhaled through the nose and passed by way of the cribriform plate of the ethmoid bone into the cranium.

46. Joe is suffering from lordosis. The extra weight that he is carrying in his abdomen shifts his center of gravity anteriorly. To compensate for this shift, the muscles of the spine exaggerate the lumbar curvature to prevent Joe from falling forward. The situation is similar to that occurring in women in late pregnancy.

47. On the basis of this evidence, you would believe the defense. If the child died as the result of violent shaking, you would expect the same type of damage as in whiplash, a dislocation of the cervical vertebrae usually at the superior portion of the spine. The damage described by the medical examiner is consistent with a child having his head stuck and pulling or twisting to one side to try to free himself. If the child pulled or twisted hard enough, he could fracture the articular processes, leading to a damaged spinal cord.

48. The large bones of a child's cranium are not yet fused, but are connected by areas of connective tissue called fontanels. By examining the bones, the archaeologist could readily see if sutures had formed yet. By knowing approximately how long it takes for the various fontanels to close and determining the sizes of the fontanels, she could make a good estimate of the child's age.

❑ Media Lab Instructor Notes

Web addresses often change. To avoid dead links, we are listing the keywords in parentheses next the to Web Explorations. Simply go to the Companion Website (http://www.prenhall.com/martini), then select the Fifth Edition of Fundamentals of Anatomy and Physiology and search using the key word to locate the current address.

Animations (Website)

- Figure 7-1—Animation with pop-up labels. The axial skeleton; suitable for self-study or perhaps lecture terminology discussion.
- Figure 7-3—Animation in play / next format with pop-up labels. The adult skull; suitable for lecture demonstration of spatial arrangement of skull.
- Figure 7-16—Animation in play / pause format. The vertebral column; the development of spinal curvature; suitable for lecture demonstration of vertebra and development or self-study.
- Rotating 3-dimensional bone images corresponding to Figures 7-3 skull, 7-8 sphenoid, 7-18 cervical vertebra, 7-19 thoracic vertebra, 7-21 sacrum.

Web Explorations (Overview)
Web exploration 1 **(TUTORIAL)**

- *Goal*—review, practice using terminology
- *Description of page*—5 images with numbers designating structures familiar to the student
- *Expectations of student behavior*—compare text and Internet images, provide terms for structures
- *Instructor's role*—assist in interpreting the images; provide methods for comparison of images
- *Special notes or further uses of exploration*—images can be copied and placed on assessment tools to reinforce knowledge; previous pages test structures entering and exiting foramina; next pages assess knowledge of nerves of facial area

Web exploration 2 (**VERTEBRAL COLUMN**)

- *Goal*—spatial understanding, application of knowledge
- *Description of page*—dual window (side bar and image screen) step-through of vertebral information
- *Expectations of student behavior*—read side bar information, click on series of footprints, draw/ compare information to create model of spinal column
- *Instructor's role*—assist in site navigation, prevent attention wandering to other links available
- *Special notes or further uses of exploration*—site includes review of skull, ribs, sternum and hyoid; may need to go to the index page and reload to get the 2-window screen to appear.

Additional Web Explorations

Should the two explorations found in the text not answer your needs, a third exploration is provided below. Your students do not have direct access to this exploration. You must provide them the address and information in the following paragraph.

Web Exploration 3

Estimated time for completion = 10 minutes

You now have practice identifying structures of the axial skeleton as they appear in artists' renderings and on photographs of disarticulated bones. Clinically however, the axial skeleton is most often examined using X-rays. Go to this Website (http://www.vh.org/Providers/TeachingFiles/NormalRadAnatomy/Images/HN/APHN2.html) and practice identifying portions of the axial skeleton as they appear in radiographs. On these Web pages you will explore actual radiographs. Compare these with the illustrations in your text, and try to identify as many structures as you can. You may find it helpful to work with other members of your class on these radiographs.

Web Exploration 3 (**RADIOGRAPHY**)

- *Goal*—spatial organization, application of knowledge
- *Description of page*—5 radiographs, 1 MRI and 5 CAT scans presented by the Virtual Hospital University of Iowa
- *Expectations of student behavior*—view images, compare with text illustrations, discuss in groups what is present
- *Instructor's role*—explanation of terminology, discussion of radiography, MRI and CAT scan
- *Special notes or further uses of exploration*—Virtual Hospital includes many reference pages designed for clinicians; students may get lost in images if not given a listing of what is present

Topic Outline				A/V Resources				
Objectives	**Chapter 7** **The Axial Skeleton** (page 1 of 3)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
2a	**I. Introduction**	7-1	3a, 6a	●	●	●		
2b	**II. The Skull**	7-2,3,4		●	●	●		●
	A. Cranial Bones		5a, 6b					
	1. The Occipital	7-5a	3b	●	●			●
	2. The Parietal Bones	7-5b	3c	●	●			
	3. The Frontal Bones	7-6	3d	●	●			●
	4. The Temporal Bones	7-7	2ab, 3efg, 5b	●	●			●
	5. The Sphenoid Bone	7-8	3hijk	●	●	●		●
	6. The Ethmoid Bone	7-9	1a, 2c, 4a	●	●			●
2c	B. Bones of the Face							
	1. The Maxillary Bones	7-10ab	5c	●	●			
	2. The Palatine Bones	7-10bc		●	●			
	3. The Nasal Bones	7-11		●	●			●
	4. The Vomer	7-11		●				●

Objectives	TOPIC OUTLINE **Chapter 7** **The Axial Skeleton** (page 2 of 3)	Figures	Strategies	A/V RESOURCES: Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	5. The Inferior Nasal Conchae	7-11		●	●			●
	6. The Zygomatic Bones	7-11		●	●			●
	7. The Lacrimal Bones	7-11		●	●			●
	8. The Mandible	7-12ab		●	●			
	9. The Hyoid Bone	7-12c			●			
	C. Summary: The Foramina and Fissures of the Skull							
2e	D. The Orbital and Nasal Complexes	7-13,14		●	●			●
	1. Paranasal Sinuses	7-14		●	●			●
	E. The Skulls of Infants and Children	7-15	3lm	●	●			
	III. The Vertebral Column	7-16		●	●	●		●
2f	A. Spinal Curvature	7-16	1b, 2d	●	●			●
	B. Vertebral Anatomy	7-17		●	●			●
	1. The Vertebral Body							
	2. The Vertebral Arch		3o, 4b					

	Topic Outline			A/V Resources				
Objectives	**Chapter 7** **The Axial Skeleton** (page 3 of 3)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	3. The Articular Processes							
	4. Vertebral Articulation							
2g	C. Vertebral Regions	7-16		●	●			●
	1. Cervical Vertebrae	7-18	1c, 2d	●	●	●		
	2. Thoracic Vertebrae	7-19		●	●	●		●
	3. Lumbar Vertebrae	7-20		●	●			●
	4. The Sacrum	7-21		●	●	●		●
	5. The Coccyx	7-21	3p	●	●			●
3	**IV. The Thoracic Cage**	7-22		●	●			
	A. The Ribs	7-22,23	6d	●	●			
	B. The Sternum	7-22a	3q	●	●			

CHAPTER 8

The Appendicular Skeleton

Introduction

A fun application of this material is comparing the appendicular skeleton of humans with that of the apes. What makes us different (skeletally) from the apes? This approach may seem far afield but it gives an excellent sense for the structure function relationships of the skeleton. It is particularly suited to an inquiry approach. Begin by asking the students how an anthropologist can tell if a new fossil walked upright or on all fours. Walking erect requires longer legs, shorter arms, a shorter wider pelvis, shorter less-curved fingers and a longer lumbar region. A good introduction to these details can be found in Chapter 1 of Roger Lewin's *The Origin of Modern Humans* (Scientific American Library, 1993).

Instructional Goals/Learning Objectives

1. To introduce the major components of the appendicular skeleton.

   a. *Identify each bone of the appendicular skeleton.*
   b. *Identify the bones that form the pectoral girdle, their functions, and their superficial features.*
   c. *Identify the bones of the upper limb, their functions, and their superficial features.*
   d. *Identify the bones that form the pelvic girdle, their functions, and their superficial features.*
   e. *Identify the bones of the lower limb, their functions, and their superficial features.*
   f. *Discuss structural and functional differences between the pelvis of a female and that of a male.*

Teaching Strategies

1. Analogies

a. The small, rounded surface of the capitulum of the humerus is reminiscent of the top of someone's head, where a "cap" would be placed.

b. The coronoid process of the ulna resembles a point in a king's crown, just as the coronoid process of the mandible. Likewise, the styloid process has the same shape as the styloid process of the temporal bone in the skull.

2. Demonstrations

a. Emphasize the structural significance of the coronoid, olecranon, and radial fossae by demonstrating how the respective processes articulate into the fossae when the antebrachium is flexed and extended.

b. There is a tendency to confuse the ulna and the radius. If you hold your arm out straight and rotate your wrist, the bone that moves Radially (i.e part of a circular path), is the Radius. You should also demonstrate that in anatomical position, the medially positioned uLna is responsible for the knobby projection that we call the eLbow at its proximal end, and is attached to the LittLe finger at its distal end.

c. The medial epicondyle of the femur can be seen as a protruding lump on the inside surface of the knee.

d. Instruct the students to run their fingers along their shin bone to illustrate the location of the anterior crest.

e. The calcaneal tendon is made easily visible if the foot is dorsiflexed. This tendon is often called the Achilles tendon, named after the character in Greek mythology whose mother held him by his heel as she dipped him into the River Styx to make him invincible. Of course, an injury in his heel, his one weakness, proved to be his undoing.

3. Vocabulary Aids

a. Many students these days might have trouble visualizing a girdle, even if they are familiar with the word. Point out that it comes from the root element "gird," which means to enclose or wrap around. Hence the pectoral girdle refers to the bones that enclose the pectus (chest).

b. The word "clavicle" comes from the same root as the words "clavichord" or "clavier," and literally means "key."

c. To avoid confusion of the coracoid and acromion processes, point out the following: "Coracoid" means "crows beak"; as one observes the process from the anterior surface, it is not difficult to imagine a bird's head and beak. "Acromion" means "extremity" or "extreme position"; the acromion process is the extreme end of the spine.

d. Remind the students that the word "trochlea" means "pulley." Upon examination of the trochlea of the humerus, one can imagine a small pulley or spool (it might be easier to visualize from the posterior surface) that the trochlear notch of the ulna wraps around.

e. The trochlear notch is sometimes referred to as the semi-lunar notch because of its half moon shape.

f. A mnemonic for the proximal carpals (lateral to medial, anatomical position):

SCAPHOID	LUNATE	TRIANGULAR	PISIFORM
SCAn	Look,	TRY	PIe.

g. A mnemonic for the distal carpals (medial to lateral, anatomical position):

TRAPEZIUM	TRAPEZOID	CAPITATE	HAMATE
TRAP the	TRAPEZOID	CAP on his	Head.

h. The word "metacarpal" means "beyond the carpal."

i. The word "phalanges" means "rows of soldiers."

j. A common spelling error of ilium is "ileum." Stress that not only is this spelling incorrect, but it is a good example of when a single letter could mean a disastrous mistake if it were misspelled on a patient's chart!

k. Your ischium is in your tush.

l. The word "acetabulum" literally means "vinegar (acetic acid) cup."

m. The word "malleolus" means "hammer." Associate the word "malleolus" with the word "mallet." The tibia with its malleolus would make an effective mallet.

n. The fibula is smaller than the tibia (like a little fib), and it is lateral to the tibia (fibuLA = LAteral).

o. The Talus is on Top and articulates with the Tibia.

p. The navicular is boat-shaped. Its name comes from the same root as naval and navigate.

q. The word "cuneiform" comes from the word that means "wedged-shaped."

4. Applications

a. The only place that the scapula is attached to another bone is at the acromion end of the clavicle, thus an individual who has a complete fracture of the clavicle will often have the appearance of their shoulder "drooped" as compared to the intact shoulder.

5. Common Student Misconceptions/Problems

a. While students do not seem to have difficulty identifying the scapula as the shoulder blade, they frequently are confused by its position, and often want to situate the medial border laterally. Have them first reach their right arm over their left shoulder, so they can palpate the spine and the acromion process. Then have them reach up to the medial border of the left scapula with their left arm (as if trying to scratch their

back), so they can feel how the medial border and angle project outward. As they observe the bone, indicate the function of the glenoid fossa. Obviously, the humerus is lateral to the fossa. If the medial border was placed in a lateral position, the humerus would hang down the middle of the back (not altogether inconvenient for scratching those hard-to-reach places).

b. Students like to associate the humerus with their funny bone. While this is an effective way of remembering the bone, note it is not spelled humorous!

c. Students usually need help distinguishing between the anatomical and surgical necks of the humerus. Indicate that the "neck" of a bone is the constricted region directly below the "head." Technically, the anatomical neck of the humerus is the rim that can be traced all the way around the base of the spherical head (but superior to the tubercles). The surgical neck is the much thinner area (which is why it is more susceptible to fracture) inferior to the head and the tubercles.

d. There is often confusion between the "coracoid" process of the scapula and the "coronoid" process of the ulna. Here is a suggestion, associate corACoid with sCApula and coroNoid with ulNa.

6. Lecture ideas

a. During the study of the appendicular skeleton, it will benefit the students if you suggest that they learn each bone with a systematic approach. They should:

1. Examine the bone, paying attention to general shape and gross anatomy.
2. Draw the bone and label the detailed characteristics.
3. Hold the bone up to their own body so that a comparison can be made for size and orientation. This procedure aids in the visualization of the bone in vivo, and prevents the confusion of the humerus with the femur, for example. During this physical comparison, identify easily distinguishable landmarks that will ascertain whether the bone is left or right. Two such landmarks are required, one to distinguish medial from lateral, and one to distinguish anterior from posterior. While the initial approach will be to learn each bone as a disarticulated unit, it is imperative that an effort be made to "fit" the bones together, both figuratively and literally. Illustrate the manner in which each bone articulates with those that are proximal or distal to it. Move the bones at the articulation to mimic the action of the articulation.

b. As each bone is examined note the landmarks that can be used to determine medial from lateral (m/l) and anterior from posterior (a/p).

1. CLAVICLE:
   (m/l): The sternal (medial) end is flat, almost as if it were sawed off.
   (a/p): when the sternal end is in position, the S shape of the bone curves away from the body and then into the body to meet the acromion process.
2. SCAPULA:
   (m/l): The glenoid fossa is lateral.

(a/p): The spine is posterior.

3. HUMERUS:
   (m/l): The round head and the more prominent medial epicondyle are medial.
   (a/p): The deep coronoid fossa is posterior.
4. ULNA:
   (m/l): The styloid process is located at the medial side of the wrist.
   (a/p): the olecranon process is posterior.
5. RADIUS:
   (m/l): The styloid process is located at the lateral side of the wrist.
   (a/p): The anterior surface of the distal extremity is smooth as compared to the posterior side.
6. COXA:
   (m/l): The acetabulum is lateral.
   (a/p): The sacroiliac joint is posterior
7. FEMUR:
   (m/l): The large, round head is medial.
   (a/p): The intercondylar fossa is posterior.
8. PATELLA:
   (p/d): The pointed apex is distal.
   (m/l): The larger of the two facets is the lateral facet.
   (a/p): The anterior surface is convex.
9. TIBIA:
   (m/l): The large malleolus is medial.
   (a/p): The tibial tuberosity is anterior.
10. FIBULA:
    (m/l): The articular facets are medial.
    (a/p): The shallower, slightly superior facet is anterior.

c. When discussing the humerus, point out that the tendon from one of the heads of the biceps brachii travels along the intertubercular groove.

d. The disc-shaped radial head is structurally unique and allows for a swivel, or rotational, movement between the radial head and the capitulum on the humerus, as well as the radial notch on the ulna.

e. As the largest bone of the body, the femur is relatively easy for students to identify. The weight, size and structure of this bone should be correlated to the function it has in the skeleton.

f. While we associate the calcaneus with our heel, it composes a large part of the posterior of our foot. It is actually the fusion of two bones, which is why there are only 7 tarsals (as compared to 8 carpals)

❑ Answers to End of Chapter Exercises

Level 1: Reviewing Facts and Terms

1. b
2. b
3. a
4. a
5. d
6. b
7. d
8. b
9. d
10. d
11. b
12. a
13. c
14. d

15. Clavicle (collar bone) and scapula (shoulder blade).

16. The acromion and coracoid processes.

17. Humerus (arm), ulna and radius (forearm).

18. extension and flexion

19. (1) scaphoid bone, (2) lunate bone, (3) triangular bone, (4) pisiform bone, (5) trapezium bone, (6) trapezoid bone, (7) capitate bone, (8) hamate bone

20. femur (thigh), tibia and fibula (leg), tarsals (ankle) , metatarsals (foot) and phalanges (toes)

21. ischium, ilium, and pubis

22. The false pelvis consists of the expanded, blade-like portions of each ilium superior to the iliopectineal line. Structures inferior to that line, including the inferior portions of each ilium, both pubic bones, the ischia, the sacrum, and the coccyx, form the true pelvis.

23. (1) talus, (2) calcaneus, (3) cuboid, (4) navicular, and (5-7) three cuneiforms

24. The pollex is the thumb, the hallux is the great toe.

Level 2: Reviewing Concepts

25. The clavicles are small and fragile, and fractures are quite common. The position of the clavicles makes them vulnerable to injury and damage.

26. The pelvic girdle consists of the ossa coxae. The pelvis is a composite structure that consists of the ossa coxae of the appendicular skeleton and the sacrum and coccyx of the axial skeleton.

27. The slender fibula parallels the tibia of the lower leg. It provides an important site for muscle attachment. It does not help in transferring weight to the ankle and foot since it is excluded from the knee joint.

28. The skeletal and muscular systems are connected to each other through tendons.

29. Since the clavicles are fragile, they are easy to break. Once this part of the pectoral girdle is broken, the assailant would no longer have efficient use of the arms.

30. The pelvic girdle transmits the weight of the body to the legs. The pectoral girdle doesn't support body weight so its bones needn't be as massive as those of the pelvic girdle.

Level 3: Critical Thinking/Clinical Application

31. The inferior iliac notch can be felt, and is at the same level as the head of the femur. The medial malleolus of the tibia can be felt at the ankle.

32. Fred may have suffered a shoulder dislocation, which is quite a common injury due to the weak nature of the glenoohumeral joint.

33. It is possible that Cindy's pelvis is not broad enough or that the angle inferior to the pubic symphysis is not large enough to accommodate natural childbirth.

❑ Media Lab Instructor Notes

Web addresses often change. To avoid dead links, we are listing the keywords in parentheses next the to Web Explorations. Simply go to the Companion Website (http://www.prenhall.com/martini), then select the Fifth Edition of Fundamentals of Anatomy and Physiology and search using the key word to locate the current address.

Animations (Website)

- Figure 8-1—Animation with pop-up labels. The appendicular skeleton; suitable for self-study or perhaps lecture terminology discussion.
- Figure 8-10—Animation in play/next format. Anatomical differences in the pelvis of a male and a female; suitable for lecture demonstration, visual interpretation of list of differences found in text.
- Rotating 3-dimensional bone images corresponding to Figures 8-2 pectoral girdle, 8-5 radius ulna, 8-6 wrist, 8-8 pelvis, 8-11 femur, 8-14 ankle.

Web Explorations (Overview)
Web Exploration 1 **(FUN FACTS)**

- *Goal*—review, add interest
- *Description of page*—main page linked to short textual descriptions of bones
- *Expectations of student behavior*—choose bones from main menu, click and read, note new information
- *Instructor's role*—guide through navigation (use back button on browser), assign structures?
- *Special notes or further uses of exploration*—simple navigational techniques required—this page may be good for novice computer users before moving to some of the more advanced links

Web Exploration 2 (**BONE QUIZ, BROKEN BONE QUIZ**)

- *Goal*—review, application of knowledge
- *Description of page*—first page is list of 10 questions, second is individual questions per page
- *Expectations of student behavior*—read and write answers to questions, click on answer to check; second quiz choose answer and read bottom description of correct answer
- *Instructor's role*—discuss bones and bone breaks; assist in applying knowledge and expanding thoughts to other organisms
- *Special notes or further uses of exploration*—questions can be copied and presented in assessment to reward those who complete the exercise.

Additional Web Explorations
Should the two explorations found in the text not answer your needs, a third exploration is provided below. Your students do not have direct access to this exploration. You must provide them the address and information in the following paragraph.

Web Exploration 3
Estimated time for completion = 10 minutes

One of the health risks associated with modern technology is carpal tunnel syndrome. Using your knowledge of the skeletal anatomy of the hand and wrist, you should be able to explain this phenomenon with accuracy. Go to this Website (http://www.ama-assn.org/insight/gen_hlth/atlas/newatlas/ctunnel.htm) and read the short explanation given and study the diagram. Turn your hand palm upward (supinate) and move your fingers while watching the tendons of your wrist. What bones are involved in this syndrome? What can be done to alleviate the constriction? Explain in writing what you believe causes carpal tunnel, including a listing of the bones associated. Why is this a more prevalent patient presentation in the computer age?

Web Exploration 3 (**CARPAL TUNNEL**)

- *Goal*—accommodation of knowledge, practical applications
- *Description of page*—short prose, good diagram of inner wrist structures from AMA
- *Expectations of student behavior*—read and study page, use text to supplement, write
- *Instructor's role*—explanation of wrist structure, help in 3 dimensional visualization
- *Special notes or further uses of exploration*—AMA links to interactive health (left side bar) can be used to personalize discussion of heart disease, weight control, exercise physiology.

Topic Outline				A/V Resources				
Objectives	**Chapter 8** **The Appendicular Skeleton** (page 1 of 2)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
1a	**I. Introduction**	8-1	6ab	●	●	●		●
	II. The Pectoral Girdle and Upper Limbs							
1b	A. The Pectoral Girdle		3a					
	1. The Clavicles	8-2	3b, 6b		●	●		
	2. The Scapulae	8-3	3c, 4a, 5a	●	●			●
1c	B. The Upper Limbs	8-4		●	●			●
	1. The Humerus	8-4	1a,2a,3d,5bc,6c	●	●			●
	2. The Ulna		1b, 2b, 3e, 5d		●	●		
	3. The Radius	8-5	6d	●	●	●		●
	4. The Carpal Bones	8-6	3fg	●	●	●		●
	5. The Hand	8-6	3hi	●	●			●
	III. The Pelvic Girdle and Lower Limbs							
1d	A. The Pelvic Girdle	8-7		●				●
	1. The Pelvis	8-8,9,10		●				●

Objectives	Topic Outline: **Chapter 8 The Appendicular Skeleton** (page 2 of 2)	Figures	Strategies	A/V Resources: Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
1e	B. The Lower Limbs							
	1. The Femur	8-11	2c, 6e	●	●	●		●
	2. The Patella	8-12		●	●			
	3. The Tibia	8-13	2d, 3m	●	●			●
	4. The Fibula	8-13	3n	●	●			●
	5. The Tarsal Bones	8-14		●	●	●		●
	6. The Foot	8-14		●	●			●
1f	**IV. Individual Variation in the Skeletal System**							

CHAPTER 9

Articulations

Introduction

Two interesting applications of the material in this chapter are artificial joint replacements and arthritis. An excellent article on hip implants by Mayor and Collier can be found in the May/June issue of *Scientific American Science and Medicine*. This article discusses the history of hip replacement as well as some of the problems that exist in terms of implant longevity. In the November/December 1996 issue, Behar and Porcelli describe the immunology of inflammatory arthritis. There are some very dramatic pictures of how serious this disease can be. Students tend to think of arthritis as a nuisance of old age. This article will give you information to dispel that misconception. A thorough understanding of immunology is not necessary for the students to understand the basic ideas of arthritis. The whole idea of autoimmune diseases seems to be something the students find interesting. The article ends with some discussion of the use of transgenic mice in studying arthritis. This is a very important new technology that our students should be made aware of. It could potentially revolutionize medical research, especially when coupled with findings from the human genome project.

Instructional Goals/Learning Objectives

1. To explain the structure and function of the different types of joints.

    a. *Contrast the major categories of joints and explain the relationship between structure and function for each category.*
    b. *Describe the basic structure of a synovial joint, identifying possible accessory structures and their functions.*
    c. *List the different types of synovial joints and discuss how the characteristic motions of each type are related to its anatomical structure.*

2. To emphasize that joint structure represents a compromise between strength and mobility, and relate this point to the common occurrence of sports-related joint injuries.

    a. *Explain the relationship between joint strength and mobility, using specific examples.*

3. To increase student awareness of the different types of movements the various joints can make, by encouraging them to examine possible movements at their own joints.

    a. *Describe the dynamic movements of the skeleton.*
    b. *Describe the articulations between the vertebrae of the vertebral column.*
    c. *Describe the structure and function of the shoulder, elbow, hip, and knee joints.*

☐ Teaching Strategies

1. Analogies

a. Describe flexion as encompassing those movements that result in a fetal position.

b. Bursae can be compared to small water balloons.

2. Demonstrations

a. Underscore that diarthroses are put together with cartilage and fibrous ligaments, so they have structural elements of both synarthroses and amphiarthroses; but, unlike synarthroses or amphiarthroses, diarthroses have a space or cavity between the bones. This cavity is lined with a synovial membrane, and the entire structure is enveloped by connective tissue known as a capsule. The cavity is what gives this joint its freedom of movement (the placement of the ligaments determines how freely moveable). A simplified example of such a structure can be demonstrated using two dowel sticks held together with a piece of rubber tubing. The sticks are the bones, the tubing is the capsule, and the space inside the tubing is the cavity.

b. Illustrate the difference between circumduction and rotation.

3. Vocabulary Aids

a. For a suture, compare the "sewing" together of two bones with short, dense fibrous connective tissue to the sewing together of two pieces of fabric with short, dense threads.

b. Dissect the word "synchondrosis" to illustrate that it literally means "together with cartilage." Note that a synchondrosis can become a synostosis if ossification of the cartilage occurs.

c. Remind the students what dense fibrous connective tissue looked like during the histology survey; long, dense fibers. The Greek word element "syndesmo" means ligament. A syndesmectomy would be the removal of a portion of a ligament.

d. When someone is "abducted," they are taken away, just as abduction takes the limb away from the body. During "adduction," the limb is "added" to the body.

e. When someone is in a prone position, they are lying face-down. Imagine the palm as the "facial" side of your hand (as it might be if you used your hand as a puppet). Pronation of the hand is to position the palm downward or posteriorly. When your hand is supinated, it is in the position of being ready to hold a bowl of soup.

f. The word "flavum" in the ligamentum flavum comes from the Latin root for yellow, the color of the ligament.

g. Stress that the Interspinous and Supraspinous ligaments get their names because they are attached to the spinous processes of the vertebrae, not because they are located on the "spine."

4. Applications

5. Common Student Misconceptions/Problems

a. If you say “joint” to Anatomy & Physiology students, they think of the knee or the elbow (or a marijuana cigarette). They do not think in terms of two bones joined together. An introduction into the topic that sets the stage for the functional/structural relationship might be helpful: When we articulate in speech, we unite or join distinct syllables and words to form continuous and distinct utterances. So it is with the articulation of the skeletal system. With the work of the muscles that pull on the bones, the skeleton produces movement. However, it is the manner in which the bones are joined that determines the degree of movement (or lack of movement). We are used to thinking of joints as a place of movement, but this is not necessarily the case. Joints, or articulations, occur any place that two bones are joined. Whether there is movement or not is dependent upon the structure of that junction.

b. For some reason, many students have a difficult time truly comprehending the concept of classification. They tend to simply memorize the terminology without regard to an organizational big picture; they just don't "get it." The text uses a functional approach to classification, with subdivisions on the basis of anatomical structure. Experience suggests that before initiating a detailed discussion regarding the functional grouping, presenting a broad picture of organization in the context of a concept map provides students a sense of order and framework on which to build.

Begin by explaining that a joint is simply where two bones are attached, and there are two questions one can ask when examining any joint: 1) How does it move? (What is its function?); and 2) How are the bones held together? (What is its structure?). Explain that if you ask those two questions of every joint in the body, you can sort them out into three "piles" based on their function and three "piles" based on their structure (like sorting playing cards, first based on the color, in which case you would have two piles; and then based on suit, in which case you would have four piles). Present the following classifications:

STRUCTURAL	FUNCTIONAL
1) held together by fibrous connective tissue	1) Immovable (synarthroses)
2) held together by cartilaginous connective tissue	2) slightly moveable (amphiarthroses)
3) held together by ligaments but containing a space or cavity between the bones, lined with a synovial membrane	3) freely moveable (diarthroses)

Explain the close correlation between the structural and functional classifications.

Point out that if two bones were "sewn" together by short, tight fibers, the joint would allow little movement. If the bones were connected with spongy cartilage, the joint would provide some movement. If the bones were "sewn" together by long fibers, such a joint might have some movement. And if the cartilage connecting the bones was rigid, there would be no movement. Hence, a synarthrosis can be fibrous or cartilaginous, and an amphiarthrosis can be fibrous or cartilaginous. It is only in the third category that there is no variation: all synovial joints are diarthrotic, and all diarthrotic joints are synovial. Because of the structural variation, you should approach the examination of joints based on their functional classification.

c. The differences between the types of joint movements are often difficult for students to comprehend. Even if they memorize the nomenclature, they find it enigmatic to apply and draw conclusions from the information. For example, "flexion" and "extension" are easily understood when applied to hinge, uniaxial joints, such as the elbow or knee. The application of those same terms to a ball-and-socket, multiaxial joint, such as the shoulder or hip is considerable more cryptic for the students. The pencil activity described in the text is an excellent visualization exercise to help explain the differences among types of movements. Learning the terminology by pairs, a word and its antonym, will make the task seem more manageable.

d. The name of the anterior and posterior ligaments can be misleading when describing their function. Stress that they are named for their placement on the tibia, but their function related to the femur uses reversed terminology. The anterior cruciate prevents the femur from sliding posteriorly off of the tibia (hence it is slack when the knee is flexed). The posterior cruciate prevents the femur from falling anteriorly off of the tibia (hence it is taut when the knee is flexed).

6. Lecture ideas

a. A summary table of the functional and structural categories of joints and the terminology for each will reinforce the information:

Classification	Fibrous	Cartilaginous	Synovial
Synarthrosis	suture	synchondrosis	X
Amphiarthrosis	syndesmosis	symphysis	X
Diarthrosis	X	X	all

b. Point out that the ankle and wrist have very different structural arrangements, requiring different terminology for angular movements. In anatomical position, the palm of the hand is in straight alignment with the arm, because the wrist is straight: but the sole of the foot is at a right angle to the leg, because the ankle is flexed. Thus, the uniaxial, angular movements of the ankle must be described with different terms than those used for the wrist.

❑ Answers to End of Chapter Exercises

Level 1: Reviewing Facts and Terms

1. d
2. a
3. c
4. c
5. d
6. a
7. b
8. c
9. b
10. b
11. d
12. c
13. c
14. a
15. b
16. a
17. d
18. a

Level 2: Reviewing Concepts

19. d
20. c
21. Menisci may subdivide a synovial cavity, channel the flow of synovial fluid, and allow variations in the shape of the articular surfaces.
22. A joint cannot be both highly mobile and very strong. The shoulder joint demonstrates the principle that strength and stability must be sacrificed to obtain mobility. The glenohumeral joint permits the greatest range of motion of any joint in the body. The relatively loose, oversized, poorly reinforced articular capsule lessens the stability of the joint, but allows a great range of motion.
23. Articular cartilages do not have perichondrium, and their matrix contains more water than other cartilages.
24. The slight mobility of the pubic symphysis joint facilitates childbirth, by spreading the pelvis to ease movement of the baby through the birth canal.
25. Height decreases during adulthood due in part to osteoporosis in the vertebrae, and also to decline in water content of the nucleus pulposus region of the intervertebral discs.
26. Contraction of the biceps brachii muscle causes flexion of the forearm at the elbow joint.
27. When the knee is "locked," it is more stable. "Locking" occurs when the leg is fully extended and the fibular collateral ligaments are tight.

Level 3: Critical Thinking/Clinical Application

28. Dave is suffering from a sprained ankle. This condition occurs when ligaments are stretched to the point where some of the collagen fibers are torn. Stretched ligaments in joints can cause release of synovial fluid, which results in swelling and pain in the affected area.
29. Bob has probably damaged his menisci. The menisci act as cushions to absorb the force of movements like jumping. When Bob landed off-balance on his right knee, the excessive force could have pushed the menisci out of place. In turn, the movement of the menisci could have

damaged the synovial membranes and/or the ligaments, resulting in swelling. This combination of factors would account for the pain and loss of mobility that he is experiencing.

30. Her pain is probably caused by bursitis, an inflammation of the bursae. Bursitis can result from repetitive motion, infection, trauma, chemical irritation, and pressure over the joint. Given the location of the pain, his case probably results from repetitive motion of practicing pitches.

❑ Media Lab Instructor Notes

Web addresses often change. To avoid dead links, we are listing the keywords in parentheses next the to Web Explorations. Simply go to the Companion Website (http://www.prenhall.com/martini), then select the Fifth Edition of Fundamentals of Anatomy and Physiology and search using the key word to locate the current address.

Animations (Website)

- Figure 9-3, 9-4—Animation in play/ next format. Angular movement / rotational movement; suitable for lecture enhancement when discussing joint function.
- Figure 9-6—Animation in play / next format. Functional classification of synovial joints; suitable for lecture enhancement when discussing joint classification, or self-study.
- Figure 9-12—Animation with pop-up labels. The knee joint; suitable for self-study or lecture enhancement while explaining the knee.
- Rotating 3-dimensional joint images corresponding to Figures 9-6 synovial joints, 9-11 hip, 9-12 knee.

Web Explorations (Overview)
Web Exploration 1 (**KNEE**)

- *Goal*—review, assist assimilation of synovial joint structure
- *Description of page*—long prose covering joint structure and then knee structure, 3 photos of cadaver
- *Expectations of student behavior*—read, reflect and write personal description of knee joint
- *Instructor's role*—prior explanation of knee joint, aid in interpretation of images
- *Special notes or further uses of exploration*—warn students of photos at the end of the page.

Web Exploration 2 (**RHEUMATOID ARTHRITIS**)

- *Goal*—critical thinking, ethical questioning
- *Description of page*—Arthritis Foundation description of research and participants
- *Expectations of student behavior*—read and reflect on personal beliefs, prepare written backing for DNA research
- *Instructor's role*—discuss arthritis, explain auto-immune disease symptoms, answer ethical questions
- *Special notes or further uses of exploration*—link to other research non-productive; can use list of contacts as expert resource for student correspondence.

Additional Web Explorations
Should the two explorations found in the text not answer your needs, a third exploration is provided below. Your students do not have direct access to this exploration. You must provide them the address and information in the following paragraph.

Web Exploration 3
Estimated time for completion = 12 minutes

Osteoarthritis of the knee can occur in seemingly healthy patients. What is this disease, and what can be done to alleviate the pain? Go to this Website (http://www.arthroscopy.com/sp07001.htm) to read an introduction to osteoarthritis of the knee. Follow the page and view an injection procedure designed to treat an arthritic knee. Who is at risk for this disease? What structure is the injected Hyalgan attempting to imitate in the healthy knee? Does this procedure make sense to you? Discuss your thoughts with your classmates using the available electronic communications options of the Companion Website.

Web Exploration 3 (**ARTHROSCOPY**)

- *Goal*—critical thinking, accommodation of joint structure
- *Description of page*—easily read prose with link video of surgical procedure
- *Expectations of student behavior*—read information, click on video and interpret what is seen
- *Instructor's role*—explanation of steroid versus non-steroid drugs and knee structure, assist in interpretation of video
- *Special notes or further uses of exploration*—home page goes back to sports medicine page (marginally scientific).

Objectives	Topic Outline: Chapter 9 Articulations (page 1 of 3)	Figures	Strategies	A/V Resources: Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	I. Introduction		5a					
1a	**II. A Classification of Joints**		5b					
	A. Synarthroses (Immovable Joints)		3ab					
	B. Amphiarthroses (Slightly Moveable Joints)		3c					
1b	C. Diarthroses (Freely Movable Joints)	9-1	2a	●	●			●
	1. Articular Cartilages	9-1a		●	●			
	2. Synovial Fluid							
	3. Accessory Structures	9-1b		●	●			
1c	4. Factors That Stabilize Joints		6a					
2a	**III. Articular Form and Function**							
3a	A. Describing Dynamic Motion	9-2		●	●			
	B. Types of Movements		5c					
	1. Linear Motion (Gliding)							
	2. Angular Motion	9-3	1a, 3d	●	●	●		

Topic Outline				A/V Resources				
Objectives	**Chapter 9 Articulations** (page 2 of 3)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	3. Rotation	9-4	2b, 3e	●	●	●		
	4. Special Movements	9-5	6b	●	●			
	C. A Structural Classification of Synovial Joints	9-6				●		
	1. Gliding Joints	9-6a		●	●			
	2. Hinge Joints	9-6b		●	●			
	3. Pivot Joints	9-6c		●	●			
	4. Ellipsoidal Joints	9-6d		●	●			
	5. Saddle Joints	9-6e		●	●			
	6. Ball-and-Socket Joints	9-6f		●	●			
3b	**IV. Representative Articulations**		6c					
	A. Intervertebral Articulations	9-7		●	●			
	1. The Intervertebral Discs							
	2. Intervertebral Ligaments		3fg					
	3. Vertebral Movements							

Topic Outline				A/V Resources				
Objectives	**Chapter 9 Articulations** (page 3 of 3)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
3c	B. The Shoulder Joint	9-9		●	●			●
3c	C. The Elbow Joint	9-10		●	●			
3c	D. The Hip Joint	9-11		●	●	●		
3c	E. The Knee Joint	9-12		●	●	●		●
	1. The Articular Capsule and Joint Cavity	9-12bc		●	●			●
	2. Supporting Ligaments	9-12a	5d	●	●			●
	V. Aging and Articulations							
	VI. Bones and Muscles							

CHAPTER 10

Skeletal Muscle Tissue

❑ Introduction

Students seem very interested in the relationship of athletic training to muscle. One particularly fruitful area to explore is the process of hypertrophy. Not all exercise causes hypertrophy. Comparing weight lifters to marathon runners makes this apparent. What types of exercise cause hypertrophy? What is the cellular mechanism of hypertrophy? A visit to a health food store will give you lots of material for discussion. Is there validity to the nutritional supplements that supposedly aid in adding muscle mass? A related area of interest is muscle spasms, Charlie horses, and post exercise muscle soreness. A good deal is known about muscle soreness and how it can be minimized. Muscle spasms are less understood. It is often useful to point to areas (especially common ones) where our knowledge is not yet complete. This gives the students a sense of anatomy and physiology as a living science and not just a collection of facts to learn.

❑ Instructional Goals/Learning Objectives

1. To familiarize students with the histology and functional organization of skeletal muscle.

   a. *Describe the characteristics and functions of muscle tissue.*
   b. *Identify the structural components of a sarcomere.*
   c. *Identify the components of the neuromuscular junction and summarize the events involved in the neural control of skeletal muscle function.*
   d. *Explain the key steps involved in the contraction of a skeletal muscle fiber.*
   e. *Compare the different types of muscle contractions.*
   f. *Describe the mechanisms by which muscle fibers obtain the energy to power contractions.*

2. To provide detailed information about skeletal muscle tissue and the functions of muscles as organs.

   a. *Describe the organization of muscle at the tissue level.*
   b. *Relate the types of muscle fibers to muscle performance.*
   c. *Distinguish between aerobic and anaerobic endurance and explain their implications for muscular performance.*
   d. *Specify the effects of exercise and aging on muscles.*

3. To describe the similarities and differences between skeletal, smooth and cardiac muscle cell structure and function.

   a. *Explain the unique characteristics of skeletal muscle fibers.*

b. *Identify the structural and functional differences between skeletal, cardiac, and smooth muscle fibers.*

c. *Discuss the role that smooth muscle tissue plays in systems throughout the body.*

❑ Teaching Strategies

1. Analogies

a. Compare the cisternae of the SR to holding tanks for the calcium ions which are held in place by the calsequestrin (a protein that is on a "quest" for calcium; in other words, it "sequesters" calcium the way a jury is sequestered before it is allowed to pass through the jury room door into the court room).

b. It is important that the student can determine the difference between "outside" and "inside" the cell, and visualize the series of membranes that connect the two. Ask the students to pretend that they are miniaturized and small enough to fit into a muscle cell, where their mission is to get a sample of sarcoplasm. They should imagine that they are swimming along the external surface of the sarcolemma (scuba gear intact), and they notice that, at regular intervals, there are rows of holes. They lay down on the sarcolemma, so that they can stick their head into one of the holes to get a better look. The hole actually is the opening to the T-tubule which looks like a long tunnel going straight down. As they swim into the tubule, they realize that they are technically still "outside" the muscle cell, because the tubule is continuous with the outside surface, and the fluid in the tubule is the same as the extracellular fluid. To get "inside" they are going to have to pass through the wall of the tubule, probably through one of the gated channels in the tubule membrane. As they pass through the T-tubule membrane, they notice that the channel actually spans two membranes, the T-tubule membrane on one side and the membrane of the room in which they are entering on the other side, like a doorway between two rooms, and when you pass through the doorway, you pass through the two walls of the rooms. Now they know that they are "inside" the cell, because they can no longer see the tunnel leading to the outside surface. They find themselves in a huge room, and they realize that they are in a terminal cisterna located on one side of a triad. As they look around, they notice that the room is crammed full of calcium ions. Each ion is trapped inside a calsequestrin cage, so that the calcium is unable to leave the room until the cage door opens, letting it float freely in the terminal cisterna. The students think about getting a sample of the fluid in the cisterna, after all, it is intracellular, but they know that they have not yet come to the sarcoplasm. They continue to journey down long, branching hallways leading from the cisternae to the sarcoplasmic reticulum. Now they realize they are but a membrane away from their goal. They quickly pass through an open channel in the membrane to find themselves in the sarcoplasm!

c. Compare the F actin to a double string of pearls that has been twisted. Each pearl is a G actin. On each G actin there is a magnetic spot that will attract myosin, but tropomyosin covers the spot, preventing it from making contact with myosin. The troponin molecules are like little men, each sitting on the twisted strand of pearls, with his legs straddling and wrapped around a single pearl (the G actin binding site). He has one hand holding the tropomyosin (this hand being the tropomyosin binding

site), and the other hand opened and waiting for Ca^{++}. When Ca^{++} comes along and lands into his open hand, the weight of the Ca^{++} makes him lose his balance slightly, and he tilts toward the Ca^{++} hand. In so doing, his other hand slides the tropomyosin away from the magnetic spot. The magnetic spot is now exposed and free to attract myosin. If the Ca^{++} is dropped from his hand, he returns to his original position, sliding the tropomyosin back over the magnetic spot.

d. Compare the myosin filaments to golf clubs of different lengths bundled together. (The shaft is the tail, and the club end is the head). The handles of two bundles meet end-to-end at the M line. Of course, unlike real golf clubs, these clubs have 2 hinges, one in the shaft towards the club end, and one at the junction of the club and the shaft.

e. The following analogy can be used to illustrate the significance of the NMJ: One way to get someone's attention in a room is to walk up and physically touch them by tapping them on the shoulder. But if you wanted to get their attention more quickly, or you required the attention of many people at once, to tap everyone's shoulder would present a logistical problem. Another way of getting attention would be to shout, "Hey, You!" This method is much more efficient. You do not have to change your location, you do not have to touch anyone, and you can get the attention of a whole group of people at once. The sound waves that you generate from your voice "diffuse" across the space in the room. Each person in the room has special receptors (their ears) that receive the sound. The reception of that sound sets up a chain of events that results in them giving you their attention.

f. The analogy presented in the text of people reaching out to pull a rope is an excellent one to use. A second analogy can be made with people sitting in a canoe (the myosin) and having to glide the canoe across the surface of the water (the actin) by reaching out with their oar (cocking), putting the oar into the water (attachment), pulling the oar causing water to be pulled along and projected toward the back of the boat (pivoting), lifting the oar out of the water (detachment), swinging the oar around (activation), and reaching out again (cocking).

A third method of demonstrating the sliding filament theory is to have a five-minute mini-drama. Have three rows of students stand. Instruct the first and third rows that they are actin, while the middle row is myosin. Arrange the students in the rows as follows (X = actin, 0 = myosin, > = facing direction):

X> X> X> X> X> X> <X <X <X <X <X <X
<0 <0 <0 0> 0> 0>
X> X> X> X> X> X> <X <X <X <X <X <X

As the students arrange themselves, prompt the class with questions: "These individuals make up the actin, would they be thin or thick filaments?," "How does the concept of a sarcomere fit into this skit?," "Which individuals make up the I band and which make up the A band?," etc. Now instruct those in the actin chain to put their hands on the shoulders of the person immediately in front of them. The myosin individuals must reach out and place their hands on the shoulders of the two nearest

actin individuals (one myosin will be touching the shoulders of two actin, one on each side). As you give the signals of "Pull!" "Release!" "Pull!" "Release!," each myosin should gently pull the two actin past them, release their hold, and grab the shoulders of the next two actin. As a wrap up, ask the class questions that rely on visualizing the process: "Does the length of either filament change?," "Does the length of the sarcomere change?," "How many times does a myosin head react with a G actin during a single twitch?," "What would happen to the amount of active tension if we pulled the thin filaments further apart before we started?" (CONTRIBUTED BY STEVE N. TRAUTWEIN, Ph.D.; SOUTHEAST MISSOURI STATE UNIVERSITY).

g. As an analogy for the length-tension relationship, imagine holding a bow and arrow. If there is no pull on the string holding the arrow, and it is released, the arrow will simply fall to the ground. If you pull the string with a slight amount of tension and then release, the arrow slides along the bridge on the bow and projects out some distance from you. The more tension you use on the string, the more room for the arrow to slide, and the further it will fly. However, if you pull on the string with too much tension, the arrow loses its connection with the bridge and falls off to the ground.

h. The all-or-none principle can be compared to turning on and off a light with a light switch. The light is either on or off (no fair using a dimmer!). How bright the room is over a period of time will depend upon how often you turn on the switch or how many switches and lights there are in the room. A single twitch is analogous to turning the light switch on and off one time. If you increase the number of times that you flip the light switch on/off, the room will seem to be continuously lit, but there will be a "blinking" or "strobing" effect caused by the short off periods (summation). Imagine flipping the light switch so frequently that the strobing effect completely disappears, and the impression is one of the light staying on all the time (fused tetanus). Put the following query before the students. "Hold your pencil very lightly. Now increase the strength of your grip gradually until you are squeezing the pencil very tightly. Now gradually decrease the strength of your grip. How are you able to perform this action of gradual increase or decrease in tension, if muscle fibers contract all-or-none?" If the light can either be on or off, how can I get the room to be brighter or less bright (again, no dimmers)? This is a good introduction to the concept of the motor unit.

i. The concepts of "same tension" vs "same length" can be illustrated by imagining an Olympic power lifter trying to lift a 300 lb weight. He grasps the bar and grunts as he gradually increases the tension, or pull, in his muscles. When the tension exceeds the 300 lb resistance, he will keep the tension constant as he shortens the muscle and lifts the weight above his knees. Now imagine the same power lifter trying to lift an 800 lb weight. He grunts as he gradually increases the tension in his muscles, but no matter how hard he tries, he cannot seem to get the pull in his muscles to exceed the 800 lb resistance. The tension in his muscles might be increasing, but his muscles are staying the same length, so he never gets the weight off the ground.

j. The following analogy can be used to illustrate the ATP needs during the different levels of activity from resting muscle to fatigue. Suppose you have a job that pays a comfortable salary (ATP and CP). When your spending activities are at a minimum, you not only have enough money to pay your bills, but you even have enough to put into a separate savings account. If you increase your spending activity, you still have enough salary to pay your bills using your checking account, but you don't have any left over to continue saving. If you increase your spending to a frenzy, you must use the money in both accounts in order to pay the bill, when you discover that isn't enough, you pull out the charge cards. If you don't stop spending and allow for some financial recovery, you will be so far into debt, that your creditors will stop the activity for you. (This works as an analogy only in the most superficial sense, but the students can usually identify with it!)

2. Demonstrations

a. Produce an image of the sliding filament theory by holding your hands, palms facing you, so that just the tips of your fingers interlace, and your thumbs stick up at right angles. Slide your fingers across each other to represent the sliding of the filaments. Observe that your thumbs (the Z bands) come closer together, but the length of your fingers stay the same. Hence, you were able to decrease the distance between your thumbs without changing the length of your fingers. As filaments slide over each other, the Z lines become closer, but the actin and myosin lengths stays the same.

b. The structural arrangement of the thin and thick filaments in smooth muscle can be compared to the plastic webbing used in grocery stores to bag oranges. The strings of the webbing represent the filaments, and the cross connections represent the dense bodies. The result is a diamond pattern. When pulled in one direction, the diamonds get long and thin (smooth muscle in its relaxed state). When pulled in the opposite direction, the diamonds get short and fat (smooth muscle in its contracted state).

3. Vocabulary Aids

a. The Greek word element "my(o)" always refers to muscle.

b. Muscle cells are called fibers because they are longer and stringier than a typical cell.

c. Associate the "tin" in actin with the word "thin." Since they are th*I*n, they look l*I*ght when viewed in the microscope; hence, they form the *I* band.

4. Applications

a. Rigor mortis is an interesting application of the biochemistry of the crossbridge cycle. Point out that the affinity of the active site on the G actin for the myosin cross-bridge is so strong, it requires the energy of an ATP molecule to detach. Thus as ATP is depleted after death, the muscles stiffen due to attached crossbridges. The rigor mortis eventually goes away as the cells are slowly destroyed and all the proteins digest.

5. Common Student Misconceptions/Problems

a. Students tend to have some difficulty with the concept of "stored energy." Underscore that as the ATPase in the cross-bridge, removes the PO_4^{3-} from the ATP, the energy that was "trapped" in that bond is not lost, simply transferred to the myosin crossbridge, allowing it to "cock" its head in a ready position (as if to cock the trigger on a gun).

6. Lecture ideas

a. Review the histology of muscle. Remind the students that muscle tissue is categorized based on its structure and neural control: 1) skeletal muscle (striated, voluntary), 2) smooth muscle (nonstriated, involuntary), and 3) cardiac muscle (striated, involuntary). Voluntary muscle is sometimes referred to as somatic muscle, whereas involuntary muscle is referred to as visceral muscle.

b. Take time to carefully examine Figure 10-1. The telescoping from gross structure to microscopic elements may seem obvious, but it frequently eludes students'. Rather than imagining the structure becoming increasingly magnified, ask them to imagine they are becoming miniaturized. They should try visualizing themselves in the page.

c. After explaining the connective tissue coverings, quiz the students, using Figure 10-1. For example: "How many muscle fascicles are in the muscle organ?," "How many muscle cells in the enlarged fascicle?," "What is the smallest unit pictured that contains all the elements needed to cause a contraction?"

d. Stress that the I band is only actin, and the H zone is only myosin. The A band is where they overlap, so it has both actin and myosin.

e. Since so much physiology is dependent upon the activity of the NMJ, it is imperative that students not only understand the structure and function but also understand the "reasoning" behind the NMJ. The events of muscle contraction occur as a result of an action potential traveling down the sarcolemma, changing the membrane permeability. The action potential is initiated in the nerve. The NMJ is where the two "meet." Its structure is necessary for the continuation of the action potential. Since the synaptic knob of the nerve does not physically touch the sarcolemma, there must be a method of getting the flow of electrons coming down the length of the nerve to continue across the cleft to the sarcolemma. If one thinks of action potentials as currents flowing down an electrical wire, cutting the wire to form a gap would interrupt the flow. The NMJ "bridges" the gap by releasing a chemical which diffuses across the space to receptors. The binding of the neurotransmitting substance to receptors on the sarcolemma initiates a change in membrane permeability and a continuation of the action potential.

f. One can compare the advantages and disadvantages of aerobic vs. anaerobic metabolism. The former produces more ATP but requires O_2; the latter doesn't require O_2 but produces less ATP.

g. When comparing the qualities of fast and slow muscle fibers, make a direct association between the attributes of each to whether they are easily fatigued or fatigue resistant. That is, fast fibers have low glycogen reserves, few mitochondria, less myoglobin, rely on anaerobic metabolism, so, logically, they would fatigue quickly. Since slow fibers are so highly vascularized, have large amounts of mitochondria and myoglobin, and go through aerobic metabolism, they are more resistant to fatigue.

h. Stress that two of the most important differences between cardiac and skeletal muscle is that 1) cardiac muscle has its own intrinsic conduction system. It does not have to rely on neural action potentials to initiate a contraction, and 2) its contractile rate and force are controlled involuntarily by the autonomic nervous system (it is classified as a visceral organ). Skeletal muscles must have neural stimulation in order to contract, and that stimulation is controlled voluntarily by the somatic nervous system (skeletal muscles are classified as somatic organs).

   Analogously, point out the most important differences between smooth and skeletal muscle are that 1) smooth muscle is not attached to the skeleton, but occurs primarily in the walls of hollow organs, and 2) its contractions are stimulated and controlled involuntarily by the autonomic nervous system (it is classified as a visceral organ).

i. Point out that there is no troponin attached to the actin of smooth muscle as seen in skeletal and cardiac muscles. Calcium ions must find a different method of controlling the binding of the myosin heads. The calcium binds to calmodulin, a free-floating protein similar to troponin. The calmodulin then turns on the myosin light chain kinase which causes the phosphorylation and cocking of the myosin crossbridge.

❑ Answers to End of Chapter Exercises

Level 1: Reviewing Facts and Terms

1. d
2. c
3. b
4. c
5. d
6. d
7. c
8. d

9. (1) skeletal muscle (2) cardiac muscle (3) smooth muscle

10. (1) produce skeletal movement (2) maintain posture and body position (3) support soft tissue (4) guard entrances and exits (5) maintain body temperature

11. (1) epimysium: surrounds entire muscle (2) perimysium: surrounds muscle bundles (fascicles) (3) endomysium: surrounds skeletal muscle fibers

12. All the muscle fibers controlled by a single motor neuron constitute a motor unit.

13. Transverse tubules or T-tubules.

14. Tropomyosin and troponin.

15. (1) active site exposure (2) cross-bridge attachment (3) pivoting of myosin head (power stroke) (4) cross-bridge detachment (5) myosin head activation (cocking)

16. (1) the frequency of motor unit stimulation (2) the number of motor units involved

17. The intrafusal fibers of the muscle spindle

18. ATP, creatine phosphate, glycogen

19. (1) aerobic respiration (2) anaerobic glycolysis

20. (1) substantial intracellular energy reserves (2) a normal circulatory supply (3) a normal oxygen concentration in the blood

21. calmodulin

Level 2: Reviewing Concepts

22. d
23. b
24. d
25. a

26. Acetylcholine released by the motor neuron at the neuromuscular junction changes the permeability of the cell membrane at the motor end plate. The permeability change allows influx of positive charge, which in turn triggers an electrical event called an action potential, that spreads across the entire surface of the muscle fiber and into the interior, via the T-tubules. The cytoplasmic concentration of calcium ions (released from sarcoplasmic reticulum) increases, triggering the start of a contraction. The contraction ends when the ACh has been removed from the synaptic cleft and motor end plate by AChE.

27. Skeletal muscle cells are large and have a high metabolic turnover. The genes contained in the multiple nuclei direct the production of enzymes and structural proteins required for normal contraction, and the presence of multiple gene copies speeds up the process.

28. The myogram records the change in tension during a contraction. There is an initial latent period after the stimulus and before the tension begins to increase. During this period the action potential in the muscle is generated and triggers the release of calcium from the SR. As the calcium removes troponin-tropomyosin inhibition the tension begins to increase. The period of rising tension is the contraction phase. It is followed by the declining tension of the relaxation phase. During this phase, calcium is being resequestered in the SR, cross-bridges are detaching, and the troponin-tropomyosin inhibition is reestablished.

29. (1) O_2 for aerobic respiration is consumed by liver cells, which need to make a great deal of ATP to convert lactic acid to glucose. (2) O_2 for aerobic respiration is consumed by skeletal muscle fibers as they restore ATP, creatine phosphate, and glycogen concentrations to their former levels. (3) The normal O_2 concentration in the blood and peripheral tissues is replenished.

30. Skeletal muscle fibers become smaller in diameter. Skeletal muscles become smaller and less elastic. Tolerance for exercise decreases. Ability to recover from muscle injuries decreases.

31. Cardiac muscle fibers are mechanically, chemically and electrically connected to one another, causing the entire tissue to resemble a single, enormous muscle fiber which performs as a functional syncytium.

32. Cardiac muscle tissue has a property called automaticity. The contractions are timed by specialized cardiac muscle fibers called pacemaker cells.

33. Acetylcholine (ACh) binds to ACh receptors at the motor end plate of the neuromuscular junctions. Blocking the binding process inhibits the ability of the muscle to contract, thus the muscle remains relaxed. This would make atracurium a useful drug to administer before surgery.

34. Muscles that are not stimulated by motor neurons on a regular basis will atrophy. Even a temporary reduction in muscle use, such as wearing a cast, can lead to some degree of muscular atrophy. Individuals who experience a permanent loss of muscle use, through paralysis for example, will experience a greater degree of atrophy than someone whose paralysis is partial or temporary. Physical therapy can offset this effect in cases where patients are temporary unable to move normally.

35. Rigor mortis is a physical state in which the muscles lock in the contracted position, making the body extremely stiff. Contraction occurs because the membranes of the dead cells are no longer selectively permeable, and calcium leaks in, which triggers contraction. Contraction persists because the dead muscle cells can no longer make ATP, which is necessary for cross bridge detachment from the active sites. Rigor mortis begins a few hours after death and lasts until approximately 15 to 25 hours later, when the lysosomal enzymes released by autolysis break down the myofilaments.

36. Visceral smooth muscle fibers are interconnected via gap junctions. Thus when one fiber fires an action potential, it is conducted quickly to neighboring cells. The action potential in uninnervated smooth muscle fibers may be the result of exposure to chemicals, hormones, oxygen, carbon dioxide, stretching, or irritation.

37. A motor unit composed of 1500 muscle fibers would likely occur in muscles involved in powerful, gross movements. Each time the motor unit is activated, all of the fibers will contract maximally. More-powerful contractions result from large motor unit activity than from activity of small motor units. Fine movements require numerous small motor units that can be individually activated.

Level 3: Critical Thinking/Clinical Application

38. Since organophosphates block the action of the enzyme acetylcholinesterase, acetylcholine released into the synaptic cleft would not be inactivated. This would allow the acetylcholine to continue to stimulate the muscles, causing a state of persistent contraction (spastic paralysis). If this were to affect the muscles of respiration (and it is likely that it would), Ivan would die of suffocation. Prior to death, the most obvious symptoms would be uncontrolled tetanic contractions of the skeletal muscles.

39. Since this is a case of competitive inhibition, you would want to increase the level of acetylcholine in the synapse. Therefore, you would want to use the drug that blocks the enzyme acetylcholinesterase. This would allow the acetylcholine concentration in the synapse to increase, thereby increasing the likelihood that the acetylcholine would bind its receptor and lead to muscle stimulation, thus alleviating the symptoms. Blocking acetylcholine would only aggravate the symptoms and make the condition worse.

40. If muscle damage occurred, the doctor would expect to find enzymes and other molecules normally found only inside the skeletal muscle cells. These molecules would be in the blood if the cell membranes were broken, allowing the cell contents to escape. Particularly significant would be enzymes associated with energy metabolism, such as CPK.

❑ Media Lab Instructor Notes

Web addresses often change. To avoid dead links, we are listing the keywords in parentheses next the to Web Explorations. Simply go to the Companion Website (http://www.prenhall.com/martini), then select the Fifth Edition of Fundamentals of Anatomy and Physiology and search using the key word to locate the current address.

Animations (Website)
- Figure 10-9—Animation in play/next format. Skeletal muscle innervation; suitable for lecture enhancement during explanation of neuromuscular junction
- Figure 10-10—Animation in play/next format. Molecular events of the contraction process; suitable for lecture enhancement explanation of sliding filament theory ion movement and protein responses.

Web Explorations (Overview)
Web Exploration 1 **(MUSCLE FIBERS)**

- *Goal*—critical thinking / visualization of myofiber
- *Description of page*—short research paper on slow and fast twitch myofibers
- *Expectations of student behavior*—read information without collaboration, group work in refining image
- *Instructor's role*—introduce research papers, assist in terminology, provide additional images to help students construct image
- *Special notes or further uses of exploration*—posters / pictures shared with class

Web Exploration 2 **(HYPERTROPHY)**

- *Goal*—critical thinking beyond text / myofiber functional anatomy
- *Description of page*—full paper on hypertrophy with many links to exercise physiology information
- *Expectations of student behavior*—read information, click on further links
- *Instructor's role*—introduce research papers, provide feedback on thought processes
- *Special notes or further uses of exploration*—explain purpose fully to avoid students clicking links before task completed; follow links to discuss exercise physiology

Additional Web Explorations
Should the two explorations found in the text not answer your needs, a third exploration is provided below. Your students do not have direct access to this exploration. You must provide them the address and information in the following paragraph.

Web Exploration 3
Estimated time for completion = 10 minutes

The sliding filament theory involves quite a few interactions. A simulation of the contraction cycle is available at this Website (http://www.bms.abdn.ac.uk/microcomputing/musclecal.html). Can you explain what you see in terms similar to those used in your test? List the steps in the order that they are depicted in the simulation. Add any information to your list that is given in

the text but not part of the simulation to complete your personal study guide for the sliding filament theory.

Web Exploration 3 (**SLIDING FILAMENT**)

- *Goal*—further clarification of sliding filament theory
- *Description of page*—
- *Expectations of student behavior*—
- *Instructor's role*—clear explanation of sliding filament theory, proper questions to enhance student observations; encourage group observations
- *Special notes or further uses of exploration*—site loads slowly; group presentations of steps leading to overall class sliding filament theory study sheet.

Topic Outline				A/V Resources				
Objectives	**Chapter 10 Muscle Tissue** (page 1 of 4)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	I. Introduction							
1a	**II. Skeletal Muscle Tissue and the Muscular System**		6a					
3a	**III. Anatomy of Skeletal Muscle**	10-1	6b	●	●			●
2a	A. Organization of Connective Tissues		3a, 6c					
2a	B. Blood Vessels and Nerves							
2a	C. Microanatomy of Skeletal Muscle Fibers	10-2	3b	●	●		●	
	1. The Sarcolemma and Transverse Tubules	10-3a		●	●			
	2. Myofibrils	10-3		●	●			
	3. The Sarcoplasmic Reticulum	10-3b	1abcd, 3c, 6d	●	●			●
1b	4. Sarcomeres	10-4,5,6,7		●	●			
	IV. Contraction of Skeletal Muscle							
	A. The Sliding Filament Theory	10-8	2a	●	●			
1c	B. The Control of Skeletal Muscle Activity	10-9a		●	●			
	1. The Neuromuscular Junction	10-9bc	1e, 6e	●	●	●	●	

Objectives	TOPIC OUTLINE **Chapter 10** **Muscle Tissue** (page 2 of 4)	Figures	Strategies	A/V RESOURCES: Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
1d	2. Excitation-Contraction Coupling	10-10			●	●		
	C. Relaxation							
	D. Length-Tension Relationships	10-11		●	●			
	V. Muscle Mechanics							
	A. Tension Production							
	1. The Frequency of Muscle Stimulation	10-12,13	1h	●	●			
	2. Internal Tension and External Tension	10-14		●	●			
	3. Motor Units and Tension Production	10-15		●	●			
1e	4. Isotonic and Isometric Concentrations	10-16	1i	●	●			
	5. Resistance and Speed of Contraction	10-17		●	●			
	6. Muscle Relaxation and the Return to Resting Length							
1f	B. Energetics of Muscular Activity		6f					
	1. ATP and CP Reserves							

TOPIC OUTLINE				A/V RESOURCES				
Objectives	**Chapter 10** **Muscle Tissue** (page 3 of 4)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	2. ATP Generation							
	3. Energy Use and the Level of Muscle Activity	10-18		●	●			
	4. Muscle Fatigue			●				
	5. The Recovery Period		1j					
	6. Hormones and Muscle Metabolism							
	C. Muscle Performance							
2c	1. Types of Skeletal Muscle Fibers		6g					
	2. Muscle Performance and the Distribution of Muscle Fibers	10-19		●	●			
	3. Muscle Hypertrophy							
2d	4. Physical Conditioning							
	VI. Aging and the Muscular System							
	VII. Integration with Other Systems	10-20			●			
	VIII. Cardiac Muscle Tissue	10-21ab		●	●			

Topic Outline				A/V Resources				
Objectives	**Chapter 10** **Muscle Tissue** (page 4 of 4)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
3b	A. Differences Between Cardiac and Skeletal Muscle Tissues		6h		●			
	1. Structural Differences	10-21c		●	●			
	2. Functional Differences							
3c	**IX. Smooth Muscle Tissue**	10-22ab		●	●			
	A. Differences Between Smooth Muscle Tissue and Other Muscle Tissues							
	1. Structural Differences	10-22b	2b	●	●			
	2. Functional Differences		6i					

CHAPTER 11

The Muscular System

❑ Introduction

Learning all the muscles of the body can be a very tedious process. A problem solving activity might make the learning a little more fun. Have the students generate a list of interesting body movements (walking, talking, blinking, swallowing, etc.) Break the class into small groups. Using their books as a resource, have each group research the muscles involved in one of the movements. Each group should then present a detailed description of the muscles involved, their location, origin, insertion, action and role in the motion. You could even include innervation. This activity can be spread out over several weeks. As you cover each major group of muscles, do a movement list involving that group (you could prepare the lists yourself ahead of time). This approach might make the dry facts come alive.

❑ Instructional Goals/Learning Objectives

1. To introduce basic mechanical principles that apply to the muscular system.

   a. *Describe the arrangement of fascicles in the various types of muscles, and explain the resulting functional differences.*
   b. *Describe the different classes of levers and how they make muscles more efficient.*
   c. *Predict the actions of a muscle on the basis of the relative positions of its origin and insertion.*
   d. *Explain how muscles interact to produce or oppose movements.*

2. To introduce the major muscle groups and their primary actions.

   a. *Explain how the name of a muscle can help identify its location, appearance, and/or function.*
   b. *Identify the principal axial muscles of the body, together with their origins, insertions, actions, and innervation.*
   c. *Identify the principal appendicular muscles of the body, together with their origins, insertions, actions, and innervation.*
   d. *Compare the major muscle groups of the upper and lower extremities, and relate their differences to their functional roles.*

❑ Teaching Strategies

1. Analogies

2. Demonstrations

a. When discussing the sternocleidomastoid, instruct the students to turn their head as if to look over their shoulder to make this muscle more visible. Then have them touch the two places of origin and the insertion while saying the name of this muscle to illustrate how its name was derived. Point out that because of the two origins, this muscle has several actions depending upon whether left and right sides are working in unison or antagonistically. Together the muscles pull the chin toward the chest. Individually, they bend the head toward the shoulder and rotate the head (the left sternocleidomastoid rotates the head to the right, the right rotates the head to the left).

3. Vocabulary Aids

a. Associate the word "rectus" with the word "erect."

b. The corrugator supercilli wrinkles the brow and makes it look like a piece of corrugated cardboard.

c. Note that the medial and lateral pterygoideus muscles are named for their origin on the pterygoid ("winged") portion of the sphenoid. The pterodactyl was a winged dinosaur.

d. When discussing the muscles of the tongue, note that the Greek word element "gloss" means "tongue." A list of words for the tongue is a glossary.

e. The levator scapulae lifts or "levitates" the scapula (like shrugging your shoulders).

f. The serratus anterior has a jagged edge, like a "serrated" knife.

g. The word "deltoid" describes the shape of this muscle, coming from the Greek "delta" (Δ), meaning triangle.

h. Stress that the supraspinatus and infraspinatus muscles get their names because they are attached to the spine of the scapula, not because they are located on the "spine."

i. When discussing the teres major and minor, point out that the word "teres" means long and round.

j. The tensor fasciae latae muscle inserts on the iliotibial tract, it appears to have a long sheet of tendon (fascia). One can be reminded of the muscle's name by remembering "The tensor fascia latae has a lotta fascia."

k. Point out that the obturator muscle has its origins on the obturator foramen.

l. The biceps femoris, the semimembranosus, and the semitendinosus compose the hamstring, these three muscles are the portion of the pig butchered as a ham. To help distinguish between the semitendinosus and the semimembranosus muscles, point out that the tendinosus is long and thin, like a tendon; the membranosus is more massive and membranous.

m. The sartorius is the longest muscle in the body. It is the muscle used when sitting on the floor with legs crossed. This position was common for tailors as they sewed. The root sartor means tailor and hence the name of the muscle.

n. The gastrocnemius muscle gets its name because of its large belly (gastric).

4. Applications

a. The rectus abdominis muscles are often referred to as the "abs."

b. The pectoralis major muscle is often referred to as the "pecs."

c. The latissimus dorsi muscle is often referred to as the "lats."

5. Common Student Misconceptions/Problems

a. If identifying (not to mention spelling) the names of the muscles and muscle groups is a difficult assignment for most students, then comprehending and predicting the action of those muscles is a Herculean task! This is perhaps because students place most of their attention on identifying the body of the muscle and think of the attachment sites as inconsequential. Even if they are required to memorize the origin and insertion of each muscle, the information that they commit to memory never seems to seep down to the cognitive level of applied knowledge. The challenge is to convince the students that without clear knowledge of how the muscles attach, there can be no comprehension of how they work. The function of each muscle organ relies on its structure, not just the structure of composition, but the structure of placement as well. Studying this chapter, accompanied by laboratory dissection, is essential for developing a complete mental image. Models of muscles can be used, but because models are rigid and do not have moveable joints, the muscles cannot be pulled and manipulated in order to observe their action. The colored plates in this chapter make an excellent cross-reference; students should be encouraged to use the book to accompany their visual, hands-on study.

b. Students are very skeptical when you tell them that muscles only pull, never push. In spite of efforts to remind them of the sliding filaments and the shortening sarcomeres, it does not make sense to them that muscles are only capable of pulling, after all, they push open doors, they push their chairs away from their desk, they push the buttons on the remote. This is why the discussion of levers is so important. Once examining the actions and forces of levers, it becomes more obvious how levers can change the direction of an applied force.

6. Lecture ideas

a. Students have often suspected that muscle terminology was "invented" and exists for the sole purpose of being the bane of their existence. Emphasizing that there is a logic to the nomenclature of muscles can help dispel some of that suspicion. Sound the muscle names out loud for the students, so that they can hear what the terms sound like. Dissect the words to point out familiar word elements. Point out that names based upon relative location tend to occur in pairs. Chances are, if there is an externus, there will be an internus; if there is a superior, there will be an inferior; etc. Encourage students to use word associations and mnemonic devices when learning the names of the muscles. They should share these learning tools with the other students in the class; in fact, a running list can be kept posted in the laboratory for everyone's perusal.

b. Point out that the actions of the superior and inferior obliques are opposite of what the names imply due to their angle of insertion. Make note of the pulley-like structure associated with the superior oblique.

c. Demonstrate that muscles must cross a joint in order to cause the movement of a bone. As the appendicular musculature is examined, point out that the body or bulk of the muscle generally exists proximal to the limb of movement and the insertion spans a joint. For example, the muscles that move the upper arm are on the shoulder and chest, the muscles that move the forearm are on the brachium, the muscles causing action of the palm and wrist are on the antebrachium.

d. Point out that flexors of the elbow tend to be on the ventral surface of the arm, whereas extensors tend to be on the dorsal surface of the arm. Then point out that because our knees bend in a different direction than our elbows, in the legs, the flexors tend to be on the dorsal surface, whereas extensors tend to be on the ventral surface. In addition, abductors are generally on the lateral surface, adductors on the medial surface.

e. The calcaneal tendon that inserts the gastrocnemius and soleus onto the calcaneus is made easily visible if the foot is dorsiflexed. This tendon is often called the Achilles tendon after the character in Greek mythology whose mother held him by his heel as she dipped him into the River Styx to make him invincible. Of course, an injury in his heel, his one weakness, proved to be his undoing.

❑ Answers to End of Chapter Exercises

Level 1: Reviewing Facts and Terms

1. b
2. d
3. d
4. d
5. c
6. d
7. a
8. b
9. a
10. b
11. b
12. b
13. c
14. a
15. b
16. d
17. a

18. (1) anatomical arrangement of the muscle fibers (2) how the muscles attach to the skeleton

19. (1) parallel (2) convergent (3) pennate (4) circular

20. unipennate-all muscle cells are found on the same side of the tendon; bipennate-muscle fibers are on both sides of the tendon; multipennate-the tendon branches within the muscles

21. In first class levers the fulcrum lies between the applied force and the resistance. In second class levers the resistance lies between the applied force and the fulcrum. In third class levers the force is applied between the resistance and the fulcrum.

22. (1) Agonist (prime mover): a muscle whose contraction is chiefly responsible for producing a particular movement. (2) Antagonist: muscle whose actions oppose that of the agonist under consideration. (3) Synergist: assists the prime mover in performing an action, and preventing movement at a joint, thereby stabilizing the origin of the agonist.

23. The axial musculature positions the head and vertebral column and moves the rib cage, assisting in the movements that make breathing possible. The appendicular musculature stabilizes or moves components of the appendicular skeleton.

24. (1) muscles of the head and neck (2) muscles of the vertebral column (3) oblique and rectus muscles (4) muscles of the pelvic floor

25. masseter, temporalis and pterygoid muscles

26. (1) support the organs of the pelvic cavity (2) flex the sacrum and coccyx (3) control movement of materials through the urethra and anus

27. (1) muscles that position the shoulder girdle (2) muscles that move the arm (3) muscles that move the forearm and hand (4) muscles that move the hand and fingers

28. (1) muscles that move the thigh (2) muscles that move leg (3) muscles that move foot and toes

29. (1) deltoid muscle (shoulder) (2) gluteus medius and maximus (3) vastus lateralis of the thigh; Injections into these thick muscle masses are preferred sites because the likelihood of piercing a blood vessel or nerve is minimized.

Level 2: Reviewing Concepts

30. b
31. b
32. b

33. The vertbral column does not need a massive series of flexors because many of the large trunk muscles flex the vertebral column when they contract. In addition, most of the body weight lies anterior to the vetebral column and gravity tends to flex the intervertebral joints.

34. The urethral and anal sphincter muscles are usually in a constricted state, to prevent the passage of urine and feces. The muscles are innervated by nerves that are under conscious control, thus the sphincters normally relax only to allow passage of wastes when the individual decides so.

35. In a convergent muscle, the direction of pull can be changed by stimulating only one group of muscle cells at any one time. When they all contract at once, they do not pull as hard on the tendon as a parallel muscle of the same size. The reason is that the muscle fibers on opposite sides of the tendon are pulling in different directions rather than working together.

36. A pennate muscle contains more muscle fibers than does a parallel muscle of the same size. A muscle that has more muscle fibers also has more myofibrils and sarcomeres, resulting in a contraction that generates more tension.

37. Lifting heavy objects becomes easier as the elbow approaches a 90° angle. As you decrease the angle or near full flexion, tension production declines, and movement becomes more difficult.

38. The muscles of mastication would be affected, therefore chewing will be inhibited.

39. Flexion at the leg and extension at the hip

Level 3: Critical Thinking/Application

40. Contraction of the frontalis muscle would wrinkle Mary's brow while contraction of the procerus would flare her nostrils. Contraction of the levator labii on the right side would raise the right side of her lip as when sneering. Obviously Mary is not happy to see Jill.

41. Jeff should do squatting exercises. If he places a weight on his shoulders as he does these, he will notice better results, since the quadriceps muscles will be working against a greater resistance.

42. As the child grasps the ice cream cone, he uses flexor muscles, principally the flexor digitorum superficialis, flexor digitorum profundus, and flexor pollicis longus. Opening his mouth requires contraction of the platysma and relaxation of the masseter, temporalis, and pterygoideus muscles. The licking action would involve the genioglossus muscle (depress and protract the tongue) and the palatoglossus muscle (elevates the tongue).

❑ Media Lab Instructor Notes

Web addresses often change. To avoid dead links, we are listing the keywords in parentheses next the to Web Explorations. Simply go to the Companion Website (http://www.prenhall.com/martini), then select the Fifth Edition of Fundamentals of Anatomy and Physiology and search using the key word to locate the current address.

Animations (Website)

- Figure 11-2—Animation in play/next format. Three classes of levers; suitable for self-study or lecture enhancement while explaining muscle functioning.
- Figure 11-3—Animation with pop-up labels. An overview of the major skeletal muscles; suitable for sequential naming of muscles during lecture presentation, or self-study.
- Rotating 3-dimensional muscle images corresponding to Figures 11-4 facial muscles, 11-14 trunk, 11-16 shoulder, 11-21 hip and thigh.

Web Explorations (Overview)

Web Exploration 1 **(MUSCLES)**

- *Goal*—drill and practice, review
- *Description of page*—three views of female body linked to muscle information pages, with further links to exercises, and related muscles
- *Expectations of student behavior*—choose area, click and copy information, refer to text for guidance
- *Instructor's role*—prior discussion of muscle anatomy and superficial musculature, help students remain on task when navigating through sequential links
- *Special notes or further uses of exploration*—best used as self-study or group work in lab setting, easy to get lost in links—remind students of BACK button!

Web Exploration 2 **(STEROID LAWS)**

- *Goal*—critical thinking, ethical questioning
- *Description of page*—informational page written by criminal lawyer who specializes in steroid cases
- *Expectations of student behavior*—read both pages and reflect on personal beliefs, prepare written support for stance
- *Instructor's role*—discuss hypertrophy, steroids, role of testosterone in muscle development
- *Special notes or further uses of exploration*—interesting outside view on physiology; links within page are tasteful and not judgmental, e-mail provided so students can question "expert" in the field.

Additional Web Explorations
Should the two explorations found in the text not answer your needs, a third exploration is provided below. Your students do not have direct access to this exploration. You must provide them the address and information in the following paragraph.

Web Exploration 3
Estimated time for completion = 5 minutes

Training the muscular system for strength or athletic excellence is fraught with conflicting advice. "No gain without pain" is often heard in locker rooms and training facilities. Is this in fact the best way to gain muscle mass and strength? To hear a different point of view, go to this Website (http://www.myodynamics.com/failure.html) and read the article by Charles I. Staley, B.Sc., MSS on the science of muscular hypertrophy and the practice of training to failure. Can you relate this to a personal experience? After reflecting on this article, write an exercise plan for yourself starting from your present fitness state and assuming your goal was to gain muscle mass. If you wish, share your plan with your classmates using the communications support on the Companion Website.

Web Exploration 3 **(FAILURE)**

- *Goal*—analytical thinking, relevance to personal experience
- *Description of page*—easily read article on exercise physiology with reputable references
- *Expectations of student behavior*—read information, interpret studies and create own meaning
- *Instructor's role*—explanation of training terminology, provide exercise information *Special notes or further uses of exploration*—bottom of page links to advertisement and MyoDynamics home page; body building information with little hype or unsuitable links

Topic Outline				A/V Resources				
Objectives	**Chapter 11** **The Muscular System** (page 1 of 3)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	I. Introduction							
	II. Biomechanics and Muscle Anatomy							
	A. Organization of the Skeletal Muscle Fiber							
	1. Parallel Muscles	11-1a		●	●			
	2. Convergent Muscles	11-1b		●	●			
	3. Pennate Muscles	11-1cde		●	●			
	4. Circular Muscles	11-1f		●	●			
1d	B. Levers		5b					
	1. Classes of Levers	11-2			●	●		
	III. Muscle Terminology							
1c	A. Origins and Insertions	11-2b			●			
1d	B. Actions							
2a	C Names of Skeletal Muscles							
1a	1. Fascicle Organization		3a					

Topic Outline				A/V Resources				
Objectives	**Chapter 11 The Muscular System** (page 2 of 3)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	2. Location							
	3. Relative Position							
	4. Structure, Size and Shape							
	5. Origin and Insertion							
	6. Action							
	D. Axial and Appendicular Muscles	11-3		●	●	●		●
2b	**IV. The Axial Muscles**							
	A. Muscles of the Head and Neck							
	1. Muscles of the Facial Expression	11-4	3b	●	●	●		●
	2. Extrinsic Eye Muscles	11-5	6b	●	●			●
	3. Muscles of Mastication	11-6	3c	●	●			
	4. Muscles of the Tongue	11-8	3d	●	●			
	5. Muscles of the Pharynx	11-9		●	●			
	6. Anterior Muscles of the Neck	11-10	2a	●	●			

	TOPIC OUTLINE			A/V RESOURCES				
Objectives	**Chapter 11** **The Muscular System** (page 3 of 3)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	B. Muscles of the Vertebral Column	11-11		●	●			●
	C. Oblique and Rectus Muscles	11-3a,11c,12	4a	●	●			●
	1. The Diaphragm	11-12b		●	●			●
	D. Muscles of the Pelvic Floor	11-13		●	●			●
2c	**V. The Appendicular Muscles**	11-14	6c	●	●	●		●
2d	A. Muscles of the Shoulders and Upper Limbs							
	1. Muscles That Position the Pectoral Girdle	11-14,15	3ef	●	●			●
	2. Muscles That Move the Arm	11-14,15,16,17	3ghi, 4cd, 6d	●	●	●		●
	3. Muscles That Move the Hand and Fingers	11-18,19		●	●			●
2d	B. Muscles of the Pelvis and Lower Limbs							
	1. Muscles That Move the Thigh	11-20	3jk	●	●			●
	2. Muscles That Move the Leg	11-21	3lm	●	●	●		●
	3. Muscles That Move the Foot and Toes	11-22	3n, 6e	●	●			●

CHAPTER 12

Neural Tissue

Introduction

An excellent way to get students interested in this material is to discuss the effects of psychoactive drugs. This allows you to motivate the study of synapses and the biochemistry of transmitters and their receptors. I usually discuss alcohol, cocaine, amphetamines and nicotine, but many more are possible. I try not to present an anti-drug (and certainly not a pro-drug) lecture. I just discuss the facts and occasionally some interesting history, such as the early use of cocaine in Coca-Cola. A comparison of the mechanisms of cocaine and Prozac as reuptake inhibitors is an interesting comparison. Almost any good neuroscience book will discuss these issues. I have come across three more popular books that have more interesting background. These would be good books to place on reserve. The oldest of the three, *Drugs and the Brain* by Solomon Snyder (Scientific American Library, 1986) is still very useful. Richard Restack's *Receptors* (Bantam, 1993) is also very good and readable. At a lower level, but very popular among the students is Gesina Longenecker's *How Drugs Work* (ZD Press, 1994).

Instructional Goals/Learning Objectives

1. To review and detail the histological organization of neural tissue.

   a. *List the two major anatomical subdivisions of the nervous system and describe the characteristics of each.*
   b. *Describe the locations and functions of neuroglia in the central nervous system.*
   c. *Sketch and label the structure of typical motor and sensory neurons and describe the function of each component.*
   d. *Classify neurons on the basis of their structure and function.*
   e. *Discuss the interactions that occur in the processing of information in neural tissue.*
   f. *List the factors that affect neural function and explain the basis for their effects on neural activity.*
   g. *Describe the patterns of interaction between neurons that are involved in the processing of information at higher levels.*

2. To review membrane phenomena and relate membrane events to information processing at the cellular level.

   a. *Explain how the resting potential is created and maintained.*
   b. *Describe the events involved in the initiation and conduction of an action potential.*
   c. *Discuss the factors that affect the speed with which action potentials are transmitted.*
   d. *Describe the structure of a synapse and the mechanism of synaptic transmission.*
   e. *Describe the major kinds of neurotransmitters and neuromodulators and discuss their effects on postsynaptic membranes.*

3. To introduce reflexes, establishing the framework for discussions in Chapter 13.

❑ Teaching Strategies

1. Analogies

a. In a simplified analogy, studying the nervous system is like explaining the electrical and computer network of an extremely complicated machine. In the previous chapters, we examined various components of the machine, peeling away systems, layer by layer, until we began to get a glimmer of just how complicated the machine is. Now we turn our attention to the data base, computer chips, and circuitry that coordinate and integrate the interactions of all the other systems.

b. Draw on the analogy made in Chapter 4 between the interaction of cells and tissues and the instruments and sections within an orchestra; only now imagine the orchestra representing the entire organism. The conductor acts as the nervous system of the orchestra coordinating the sounds, tempo, and dynamics of the music. Of course the notes, the language of music, have already been recorded and passed on from musician to musician, but the conductor must arrange, interpret, and synchronize the music in order to blend the sounds of the individual sections. Through a constant process of listening, evaluating, and directing, the musicians respond to her guidance, so that instead of cacophony there is harmony.

c. The following extended analogy may help the students integrate a lot of information:

NEURON (CELL BODY) VS. NERVE FIBER. Correlate the physical and operational relationships. Cell bodies cannot conduct electrical impulses but they can integrate and synchronize information. Dendrites and axons act only to bring the information to and from the cell bodies. Compare the cell bodies to relay or switching stations, while the fibers are the railroad tracks leading to and from the relay stations. (The trains are the current running along the tracks).

AFFERENT VS. EFFERENT. Underscore that these terms indicate the direction of conduction. To avoid collisions, the railroad tracks must be one-way. If the railroad tracks are in-bound or lead to the relay stations, they are afferent. If they are out-bound or lead away from the relay stations, they are efferent.

SENSORY VS. MOTOR. In contrast, these terms indicate the type or function of conduction. Since the function is related to the direction, these terms are interchangeable with afferent and efferent. All sensory passengers must first go to the station for the planning of their outbound motor trip. No passenger can go directly from their departure spot to their destination without first passing through the station. Arriving or in-bound (afferent) trains carry passengers into the station; departing or out-bound (efferent) trains carry passengers out of the station.

DORSAL ROOT VS. VENTRAL ROOT. Parallel the anatomical locations to the functional processes. Again, to avoid collisions, arriving trains must enter the rear of the station on the afferent tracks; departing trains must leave from the front of the station on the efferent tracks.

Get the students to equate:

INPUT	OUTPUT
afferent	efferent
sensory	motor
dorsal	ventral
dendrite	axon (on a cellular level)

d. Underscore the functional and structural relationship with the color of neural tissue; i.e., gray = center of integration and white = area of nerve conduction. You are putting away Christmas tree lights, and you have stretched all the strands out on the floor, parallel to one another, so that they can be wrapped up without tangling. You notice that the wires between the lights that carry the current from light to light, are long, parallel lines. They don't take up much room; in fact you could bind them together with masking tape. You imagine that if you were to cut into the bundle, you would see all the copper wires. On the other hand, the areas of the strands that contain the lights, form large wads of bulbs when laid together. This mass of bulbs would be more difficult to wrap with masking tape and would appear differently in a cross-sectional view.

e. Comparing ion channels to doors is an effective analogy. Passive channels are like a door that is always slightly ajar. Gated channels can be in any one of three states. For voltage gated channels the state depends on the membrane voltage. Compare the states to 1) a closed door (closed but capable of opening), 2) an opened door (activated), and 3) a closed and locked door (closed and incapable of opening; inactivated). For chemically gated channels the state depends on the presence or absence of the appropriate chemical. For mechanically gated channels the state depends on the state of stretch of the membrane. Using the same analogy: 1) one class of door needs a chemical key to turn the door knob, 2) another class needs an electrical key, and 3) a third class needs a structural key to turn the door knob before it will open. Make careful distinction between the state of a gated channel (i.e., its condition of openness) and the class of a gated channel (i.e., what is required to open the door).

f. The door analogy can be extended to help the students understand graded potentials vs. action potentials. Stress that a current is simply a flow of electrical charges, and the current established in a graded potential is local; i.e., it involves sodium ions flowing through only a few doors in the membrane. Obviously, the more sodium doors that can be opened, the more sodium will diffuse into the cell. These doors are usually chemically gated and located in a postsynaptic membrane. An action potential is complete, all the sodium doors are open. Imagine a spring-loaded mechanism that will automatically open all the doors once a certain number of sodium doors open (threshold). Suppose there are 50 doors. In order to get an action potential going, we need to open all 50 doors. Graded potentials will only open a few doors at a time, but if we can get enough of a graded potential to open at least 10 doors, the spring loaded mechanism will release, and all 50 doors will swing open.

g. Another method of depicting threshold and action potentials is to imagine that you must move a boulder over a hill to the other side (reminiscent of Sisyphus). You

know that if you can just get the boulder over the crest at the top of the hill (the threshold), then it will automatically roll down the opposite side. You can administer individual (graded) pushes, in which case the boulder rises only part of the way up the hill, but never makes it over the top. However, if many small, graded pushes are applied rapidly, eventually you will reach the top and can complete the total action.

h. There are many analogies that can be used to illustrate the all-or-none principle.

Continuing with the boulder-up-the-hill analogy: Once the boulder crosses the threshold, it will make a complete descent down the other side of the hill. The descent is independent of how it got to the crest.

The example given in the text of the trigger releasing the firing pin in a gun at a set point, regardless of the pressure applied on the trigger is an effective analogy.

The light switch analogy used in Chapter 10 during the discussion of the all-or-none principle of muscle contraction will also illustrate the concept here. The light is either on or off, and turning it on has nothing to do with how hard you flip the switch. Once the switch makes the connection, the circuit is complete, and the light goes on.

You're going to light the gas grill in order to barbecue some burgers. You open the valve to the gas source, and then light the burner with a match. The effect would be exactly the same if you used a flame-thrower (though you might singe the lawn a bit). The flame in the burner is independent of the fire source used to light it.

2. Demonstrations

a. The "wave" observed at football games is frequently used to illustrate the continuous propagation of the action potential. With some minor modifications, you can have the students participate in an activity that demonstrates the same idea. Have the students stand and hold hands in a semicircle around the room. This line represents a neuron (the semicircle, rather than a straight line, lets everyone see what is happening all along the "neuron"). You are the stimulus. Position yourself at one end of the line. Tell the students that you are going to start the action potential by touching the first student's left arm. When you touch the left arm of the first student, he raises the arm and follows that action by raising his right arm. Since he is holding the hand of the second student, this raises the left arm of the second student. When the second student feels his left arm going up, he raises his right arm. This raises the left arm of the third student who then raises his right arm. In the meantime, the student #1 lowers his left arm. After student #2 has raised his right arm, he lowers his left arm. As each student raises his right arm, he lowers his left arm. The result is a wave of "excitement" down the length of the neuron. You can repeat the process following successive stimuli, and illustrate that several nerve impulses can be traveling down the length of the nerve at the same time. If you stimulate before the student #1 gets his left arm down to resting position, you can illustrate the refractory period (absolute, if his arm is straight up, or relative, if his arm is on its descent). The exercise illustrates several concepts:

1) The stimulus must reach threshold, you must touch student #1 hard enough for him to feel it or the neuron won't fire.
2) The neuron demonstrates the all-or-none principle, because it either carries an impulse or it doesn't, and the impulse is the same, regardless of the strength of the stimulus (as long as it is threshold).
3) Each part of the neuron returns to its resting state after the nerve impulse has passed it and can then transmit another impulse.
4) If the neuron is in the absolute refractory period, it cannot respond, no matter how strong the stimulus.
5) A neuron can carry more than one impulse at the same time.
6) An action potential is unidirectional.

(CONTRIBUTED BY CHARLENE L. NEWBY, M.S., B.S., M.T., (ASCP); LAKESHORE TECHNICAL COLLEGE).

3. Vocabulary Aids

a. When discussing astrocytes note that the word "astro" means "star" and denotes the shape of these cells.

b. To remember which ions are distributed where, use the following word association: You keep your POT (POTassium) inside the house to cook bacon and eggs (proteins), but the SOD (SODium) is outside for growing CLover (Chloride).

c. To remember that the inside of a cell is negatively charged, associate the "N" in iNside with the "N" in Negative and the "O" in Outside with the "O" in pOsitive.

4. Applications

a. Many drugs act at synapses. Prozac and cocaine make a good comparison.

5. Common Student Misconceptions/Problems

a. The most obvious concept, and yet the most difficult for students to integrate, is that the nervous system operates as a complete circuit of events; a circuit that follows the pattern of input, integration, and output that was established in Chapter 1 with the definition of homeostatic balance. This circuit is not just an operational pathway, but a physical pathway; thus, understanding the physiology of the nervous system is dependent upon understanding the anatomical layout.

b. Correlate the function of the neuron with its structure. Students sometimes assume that since there are three categories in each method of classification, then there must be a one-to-one relationship. If unipolar are sensory neurons, and multipolar are motor neurons, then bipolar must be interneurons.. ..(NOT!).

As each functional type of neuron is discussed, create a schematic drawing of the organization of the NS. Draw a box representing a receptor and from it, draw a unipolar, afferent, sensory neuron leading from the PNS to the CNS through the

dorsal surface. (Draw a circle to represent the CNS). Stress that the cell body of the sensory neuron is outside the CNS (a ganglion). Now draw an interneuron, emphasizing that it is multipolar. Continue by drawing the multipolar, efferent, motor neuron from the CNS (ventral root) to a second box representing the effector. Stress that the cell body of the motor neuron is within the CNS (the horn). Reiterate the function of each neuron, and emphasize the unidirectional conduction. Review the concept of visceral vs. somatic. Combining the terms, give students examples of neural pathways and ask them if they are visceral afferent, visceral efferent, somatic afferent, or somatic efferent. Try erasing part of the motor neuron, and ask the students, "if there were an injury that involved the severing of this neuron (don't name it), would it probably grow back? Why or why not? Would the result be numbness or paralysis?" Another thought question: "When the dentist gives you Novocaine, does it affect sensory neurons or motor neurons? Explain."

c. Students can understand the chemical gradients because they can "see" that sodium is different than potassium and chloride is different than proteins, but the electrical gradient is more difficult to reason. Their logic is that positively charged sodium ions outside the cell would somehow equal the positively charged potassium ions inside the cell, so there should not be a charge gradient. Emphasize that the numbers are not equal, since potassium can "leak" out faster than sodium can “leak” in. (Define "leakiness" as membrane permeability). Also note that, since the membrane is more permeable to potassium than to sodium, the resting membrane potential is established by the potassium efflux rather than the sodium influx.

6. Lecture ideas

a. Stress that the nervous system works along with the endocrine system to control and regulate the other systems of the body. It is the structure of these two systems that determines the nature of their function. The nervous system is quick to respond, and its effects are short-lived. In contrast, the endocrine system is slower to respond, and its effects are longer lasting. It is the "marriage" of the nervous and endocrine systems that provides such a complementary method of control.

b. Note that ependymal cells are epithelial cells of the CNS, so they are located on free surfaces.

c. It is not as clear in a unipolar neuron where the dendrite ends and the axon begins, since the processes are continuous. Use the cell body as a guide to determine where the axonal hillock begins.

d. Make note that the release of the ACh from the presynaptic membrane is a result of effecting voltage-regulated channels, while the channels that are opened when ACh attaches on the postsynaptic membrane are chemical-regulated channels.

❑ Answers to End of Chapter Exercises

Level 1: Reviewing Facts and Terms

1.	c	8.	c	15.	a
2.	b	9.	c	16.	a
3.	a	10.	b	17.	c
4.	d	11.	a	18.	b
5.	c	12.	b	19.	d
6.	c	13.	a	20.	a
7.	d	14.	b		

21. (a) brain and spinal cord (b) cranial & spinal nerves Efferent division-consists of the somatic nervous system and the autonomic nervous system. Afferent division-consists of receptors and sensory neurons.

22. (1) neurons- The neurons are responsible for transmission of nerve impulses. (2) neuroglia- The neuroglia are supporting cells.

23. (a) astrocytes (b) microglia

24. (1) satellite cells (2) Schwann cells

25. (1) anaxonic (2) unipolar (3) bipolar (4) multipolar

26. (1) sensory neurons-transmit impulses from the PNS to the CNS (2) motor neurons-transmit impulses from the CNS to peripheral effectors (3) interneurons (association neurons)-analysis of sensory inputs and coordination of motor outputs

27. (1) the conduction of one or more action potentials along an axon (b) the chemical transmission of signals across one or more synapses

28. Voltage-regulated channels open or close in response to changes in the transmembrane potential. Chemically regulated channels open or close when they bind specific extracellular chemicals. Mechanically regulated channels open or close in response to physical distortion of the membrane surface.

29. (1) The change in the transmembrane potential decreases with distance. (2) The graded potential spreads passively due to local currents. (3) The graded potential may involve either depolarization or hyperpolarization. (4) The stronger the stimulus, the greater the change in the transmembrane potential and the larger the area affected.

30. The properties of the action potential are independent of the relative strength of the depolarizing stimulus.

31. The membrane depolarizes to threshold. Next, voltage-regulated sodium channels are activated, and the membrane rapidly depolarizes. The sodium channels are then inactivated, and potassium channels are activated. Finally, normal permeability returns.

The voltage-regulated sodium channels start to become activateable again partway through the repolarization process; the voltage-regulated potassium channels begin closing as the transmembrane potential reaches threshold levels.

32. An action potential arrives, and the synaptic knob depolarizes. Next, extracellular calcium ions enter the synaptic knob and trigger the exocytosis of Ach. The Ach binds, and the postsynaptic membrane depolarizes. Finally, Ach is removed by AchE.

33. pH changes, ionic changes, and temperature changes

Level 2: Reviewing Concepts

34.	b	38.	a
35.	d	39.	a
36.	c	40.	c
37.	b	41.	a

42. Neurons lack an important organelle complex, the centrosome. Neural stem cells are not present in the CNS, and CNS neurons usually lose their centrioles during differentiation, making cell division impossible.

43. An axon may branch along its length, producing branches collectively known as collaterals. Collaterals enable a single neuron to innervate several other cells, a process called divergence.

44. Axoplasmic transport is the movement of products synthesized in the cell body out to the synaptic knobs. Retrograde flow is the movement of materials toward the cell body.

45. In continuous conduction, an action potential appears to move across the membrane surface in a series of tiny steps; continuous conduction occurs in unmyelinated axons. In saltatory conduction, only the nodes along the axon can respond to a depolarizing stimulus; saltatory conduction occurs in myelinated axons.

46. Resting potentials are more negative in muscle fibers. Action potentials last longer in muscle fibers than in nerve fibers. Muscle fibers conduct action potentials at a relatively slow speed.

47. Neurotransmitters are chemicals that are often classified as excitatory or inhibitory on the basis of their effects on postsynaptic membranes. Neuromodulators are compounds that influence neurotransmitter release or the postsynaptic cell's response to the neurotransmitter.

48. Temporal summation is the addition of stimuli occurring in rapid succession. It occurs at a single synapse and is active repeatedly. Spatial summation occurs when simultaneous stimuli have a cumulative effect on the transmembrane potential. It involves multiple synapses that are active simultaneously.

49. Divergence permits the broad distribution of a specific input, while in convergence

several neurons synapse on the postsynaptic neuron, permitting variable control of motor neurons by providing a mechanism for their voluntary and involuntary control.

50. The synthesis, release, and recycling of neurotransmitter molecules; the movement of materials to and from the cell body via axoplasmic flow; recovery from action potentials

51. Electrical synapses occur between neighboring cells that are connected by gap junctions. Gap junctions allow for the direct passage of electrical current through a continuous cytoplasm, so activity in electrically coupled cells is nearly simultaneous. Chemical synapses involve the release, diffusion, and binding of a neurotransmitter in response to an action potential in the presynaptic cell, before electrical activity can be generated in the postsynaptic cell. Chemical synaptic transmission thus takes more time to occur, relative to electrical synaptic transmission.

52. During long-term strenuous physical activity, neuromodulators known as endorphins are released in the brain. Endorphins are structurally similar to morphine, and relieve pain by suppressing the release of the neurotransmitter Substance P from pain neurons.

53. Action potentials travel faster in myelinated fibers. Destruction of the myelin sheath slows the time it takes for motor neurons to communicate with their effector muscles. This delay may result in varying degrees of uncoordinated muscle activity and paralysis. Cumulative sensory and motor losses may eventually lead to generalized sensory deficiencies and muscular paralysis.

Level 3: Critical Thinking/Application

54. Brain tumors result from uncontrolled division of neuroglial cells. Unlike neurons, neuroglial cells are still capable of cell division. In addition, cells of the meningeal membranes can give rise to tumors.

55. The kidney condition is apparently causing Harry to retain potassium ions. As a result, the concentration of potassium ions in the extracellular fluid is higher than normal. Under these conditions, less potassium will diffuse from heart muscle cells than normal, resulting in a resting potential that is less negative (more positive). This change in resting potential will move the transmembrane potential closer to threshold, so it will be easier to stimulate the muscle. This in turn accounts for the increased number of contractions that produces the rapid heart rate.

56. In order to reach threshold, the postsynaptic membrane would have to receive enough neurotransmitter to produce an EPSP of 20 mV (10 mV to reach threshold and 10 mV to cancel the IPSPs produced by the inhibitory neurons). Since each neuron releases enough neurotransmitter to produce a change of 2 mV, 10 of the 15 excitatory neurons would have to be stimulated to produce this effect by spatial summation.

57. A major reason that newborn infants cannot roll over, sit, or walk, is that a large number of peripheral neurons are not yet myelinated. Without myelination, information concerning limb movement and body position moves slowly to the brain, and motor responses move slowly to the muscles. In other words, by the time the brain is aware of

limb movement or position and issues a motor command, the limb has already changed movement or position. When the motor response reaches the skeletal muscle, the response is no longer appropriate. As the peripheral neurons gradually become myelinated, information flow and processing speeds up and we can see improved balance, coordination, and capabilities.

58. Initially, the recording should show normal action potentials in response to the constant stimulation. After 50,000 to 100,000 action potentials have passed, the recording will start to indicate less responsiveness from the neuron, and ultimately the neuron will fail to respond to the stimulus. Since very few ions actually move across the membrane during an action potential, neurons can carry thousands of action potentials before the concentrations of sodium and potassium ions have to be reestablished. To achieve this requires the activity of the sodium-potassium pump. Blocking ATPase activity would shut down the pump, and the cell would not be able to maintain the necessary gradients of sodium and potassium ions. As a result, the membrane will not be able to respond to stimulation until the ion concentration gradients are reestablished.

❑ Media Lab Instructor Notes

Web addresses often change. To avoid dead links, we are listing the keywords in parentheses next the to Web Explorations. Simply go to the Companion Website (http://www.prenhall.com/martini), then select the Fifth Edition of Fundamentals of Anatomy and Physiology and search using the key word to locate the current address.

Animations (Website)

- Figure 12-15—Animation in play/next format. Generation of action potential; suitable for lecture enhancement during explanation of action potential
- Figure 12-17—Animation in play/next format. Saltatory propagation along myelinated axon; suitable for lecture enhancement explanation of myelination; animation cycles beyond text image.

Web Explorations (Overview)
Web Exploration 1 **(NERVE IMPULSE)**

- *Goal*—clarification of / experimentation with nerve impulse
- *Description of page*—action potential experiment
- *Expectations of student behavior*—learning system first, then experimenting with concentrations
- *Instructor's role*—imperative that page use be explained, perhaps in lecture setting; guide students through what is being depicted; provide hints as to what concentrations to alter and what to graph
- *Special notes or further uses*—site loads slowly due to Java Applets; click first on concentrations and note beginning levels; click on variables to plot to indicate Na^+ (green), K^+ (blue) and Im (red); click Membrane AP to run AP and get graph of changes in voltage, Na and K; experiments can include changing Na levels, K levels, axon diameter or stimulus amplitude and duration; clicking on reset parameters will restore all initial values

Web Exploration 2 (**CHRISTOPHER REEVE**)

- *Goal*—clarification / critical thinking role of neuroglia
- *Description of page*—CR Foundation News page embedded within Foundation website
- *Expectations of student behavior*—scroll to portion directed in text, potential extraneous clicks
- *Instructor's role*—preparatory instruction in neuroglia, spinal cord injury explanation
- *Special notes or further uses of exploration*—good site for launching into web; ask students for current articles

Additional Web Explorations
Should the two explorations found in the text not answer your needs, a third exploration is provided below. Your students do not have direct access to this exploration. You must provide them the address and information in the following paragraph.

Web Exploration 3
Estimated time for completion =

The text describes many neurotransmitters. Due to the effects of serotonin on the limbic system, much is known about this particular neurotransmitter. Read the review article on serotonin (5-HT) found at (http://fairlite.com/ocd/articles/ser90.shtml). Think about what can be done with the knowledge of serotonin's actions presented in this review. Should this information be used in medicine? Collect your thoughts on the ethical use of research information in medicine. Prepare a justification of your position on the potential uses of serotonin in human medicine based on the information presented in the article. If you wish, the Website's bulletin board offers an avenue for sharing your ideas with your classmates.

Web exploration 3 (**SEROTONIN**)

- *Goal*—critical thinking / ethics and medicine
- *Description of page*—article taken from *Drug Topics*, October 10, 1994, p.108
- *Expectations of student behavior*—reading and writing notes
- *Instructor's role*—interpret difficult passages, define terms, support neophyte thought processes
- *Special notes or further uses of exploration*—page leads to many questions in neurotransmitter research; create ethics bulletin board and allow students to voice ethical concerns arising from news articles, research or other sources

Objectives	TOPIC OUTLINE	Figures	Strategies	A/V RESOURCES: Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	Chapter 12 Neural Tissue (page 1 of 4)							
	I. Introduction		1ab, 6a					
1a	**II. An Overview of the Nervous System**	12-1	1c, 5a	●	●			
	III. Neurons							
	A. Neuron Structure	12-2		●	●		●	●
	1. The Cell Body	12-2		●	●			●
	2. The Dendrites	12-2		●	●			●
	3. The Axon	12-2		●	●			●
	4. The Synapse	12-3		●	●			
1d	B. Neuron Classification							
	1. Structural Classification	12-4	6c	●	●			
1c	2. Functional Classification	12-5	5b	●	●			
1b	**IV. Neuroglia**	12-6		●	●			
	A. Neuroglia of the Central Nervous System							
	1. Ependymal Cells	12-7	6b	●	●			

Objectives	Topic Outline: **Chapter 12 Neural Tissue** (page 2 of 4)	Figures	Strategies	A/V Resources: Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	2. Astrocytes	12-7b	3a	●	●			
	3. Oligodendrocytes	12-7b	1d	●	●			
	4. Microglia	12-7b		●	●			
	B. Neuroglia of the Peripheral Nervous System	12-7, 8		●	●			●
	1. Demyelination							
	V. Neurophysiology	12-10		●	●			
2a	A. The Transmembrane Potential	12-11	3bc, 5c	●	●		●	
	1. Passive Forces	12-11		●	●			
	2. Active Forces: The Sodium-Potassium Exchange Pump							
	B. Changes in the Transmembrane Potential							
	1. Membrane Channels	12-11, 12		●	●			
	C. Graded Potentials	12-13,14		●	●			
	1. The Distribution and Importance of Graded Potentials							

Objectives	TOPIC OUTLINE **Chapter 12** **Neural Tissue** (page 3 of 4)	Figures	Strategies	A/V RESOURCES Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	D. Action Potentials						●	
	1. The All-or-None Principle		1gh				●	
2b	2. Action Potential Generation	12-15	2a	●	●	●	●	
2b	3. Action Potential Propagation	12-16, 17		●	●	●	●	
2c	4. Axon Diameter and Propagation Speed							
	5. Action Potentials in Muscle Tissues							
1e	**VI. Synaptic Activity**							
	A. Electrical Synapses							
2d	B. Chemical Synapses						●	
2e	1. Cholinergic Synapses	12-18	6d	●	●			
2e	2. Other Neurotransmitters							
	3. Neuromodulators							
	4. How Neurotransmitters and Neuromodulators Work							

Topic Outline				A/V Resources				
Objectives	**Chapter 12** **Neural Tissue** (page 4 of 4)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	VII. Information Processing							
	A. Postsynaptic Potentials							
	1. Summation	12-20, 21		●	●			
	B. Presynaptic Inhibition and Facilitation	12-22		●	●			
	C. The Rate of Action Potential Generation							
1g	**VIII. Higher Levels of Organization and Processing**							
	A. Functional Organization	12-23		●	●			
	B. Anatomical Organization	12-24		●	●			
	IX. Integration with Other Systems	12-25			●			

CHAPTER 13

The Spinal Cord and Spinal Nerves

Introduction

Two interesting applications of this chapter are spinal anesthesia and spinal cord injuries. Many of the students are familiar with the term epidural block and may even have had one. You might ask for a volunteer to discuss their experience with this procedure. This can then motivate a discussion of the anatomy involved. Spinal cord injuries are fairly common and don't have a particularly good prognosis. A discussion of why this is will be of interest to the students. There are a number of new approaches being tried to improve the outcome of this type of damage. A good reference for both of these topics is the Applications Manual that accompanies the Martini text.

Instructional Goals/Learning Objectives

1. To describe the normal anatomy of the spinal cord. For classes with a clinical emphasis, stress the link between the anatomical organization of the spinal cord and the observed effects of spinal injuries.

   a. *Discuss the structure and functions of the spinal cord.*
   b. *Describe the three meningeal layers that surround the central nervous system.*
   c. *Explain the roles of white matter (axons) and gray matter (neuron cell bodies) in processing and relaying sensory and motor information.*
   d. *Describe the major components of a spinal nerve.*

2. To examine the origins and distribution of spinal and peripheral nerves. Review the innervation of muscle groups as covered in Chapter 11.

   a. *Relate the distribution pattern of spinal nerves to the regions they innervate.*

3. To introduce the mechanics of neural control mechanisms using the relatively simple reflexes of the spinal cord. This pattern will be elaborated upon in Chapters 14 and 15.

   a. *Describe the process of a neural reflex.*
   b. *Classify the different types of reflexes and explain the functions of each.*
   c. *Distinguish between the types of motor responses produced by various reflexes.*
   d. *Explain how reflexes combine to produce complex behaviors.*
   e. *Explain how higher centers control and modify reflex responses.*

4. To introduce the organization of the autonomic nervous system, establishing the background for Chapter 16.

❑ Teaching Strategies

1. Analogies

a. Stress that nerve conduction must travel from sensory to motor and the pathways are one-way roads, like the east- and west-bound lanes of a highway. The spinal nerves represent the entire highway bed, so while the lanes are physically separated by a median and traffic direction is controlled by DO NOT ENTER signs, a single spinal nerve can be made up of both east and west-bound lanes (the spinal cord is analogous to the clover leaf).

2. Demonstrations

a. "Act out" as many of the reflexes as possible in order to enhance the verbal descriptions with visual cues.

3. Vocabulary Aids

a. The literal translation of dura mater is "tough mother." It was named because of the similarities it had to the tough membrane that forms over fermenting wine, sometimes referred to as the "mother" of the culture. At one time, it was believed that the meninges were the mother of all the other membranes in the body.

b. The network of fibers in the arachnoid mater gives this layer a "webby" appearance; hence, the use of the word arachnoid in reference to spider webs.

c. The translation of pia mater is "thin mother," named because it is so delicately thin.

d. Point out that the prefixes used to describe the connective tissue layers of the nerves are the same as those used to describe the connective tissue wrappings of muscles.

4. Applications

a. Peripheral neuropathies can occur in the hands of someone using crutches that are too long and put constant pressure on the radial nerve.

5. Common Student Misconceptions/Problems

a. Sometimes students are puzzled by the fact that the anterior horns do not visually connect with the ventral roots in the manner that the posterior horns connect from the dorsal roots. Because of a visual interruption made by the anterior column, it is hard for them to imagine the motor neuron extending from the anterior horn through the ventral root. Point out that the axon of the motor neuron is usually myelinated, and so it would appear white.

b. Use Figure 13.5 to illustrate the arrangement of spinal nerves. Students will tend to be confused by the details and lose sight of the significant patterns. Point out and reinforce the following details:

1. Sensory fibers enter via the dorsal root. Motor fibers leave via the ventral root.
2. Sensory cell bodies are located in the dorsal root ganglion in the PNS. Motor cell bodies (not drawn) are located in the ventral horn in the CNS.
3. The synapses from the axonal ends of the sensory fibers are located in the dorsal horn, but synapses from somatic sensory neurons are more dorsal than those from visceral sensory neurons. The cell bodies of the motor neurons are located in the ventral horn. but the cell bodies for somatic motor are more ventral than those for visceral motor.
4. Somatic motor pathways have one cell, with the soma in the CNS and an axon that extends through the spinal nerve to the skeletal muscle. Visceral motor pathways have two cells: the first, with a soma in the CNS and an axon extending through the white ramus to a ganglion (hence the name preganglionic): the second, with a soma in the ganglion and an axon extending through the gray ramus to the visceral organ (hence the name postganglionic.)
5. Sensory fibers can converge from several areas. Motor fibers diverge to several areas. Events happening in one segment can ascend to or descend from other segments. Pose questions as a way of reviewing the material. For example, "Give me examples of a visceral sensory organ, a visceral motor organ, a somatic sensory organ, and a somatic motor organ." "What color is the tissue in the ventral root?" "If I have a stomach ache, which pathway would be involved?," "Why is the ramus of the preganglionic fiber white while the ramus of the postganglionic fiber is gray?," etc.

6. Lecture ideas

a. Distinguishing the structural anterior and posterior surfaces will be important when discussing the functional dorsal and ventral roots. Have the students practice determining front from back on unmarked pictures of a spinal cord section. As you point out the dorsal root ganglia, ask the students to tell you what ganglia are. Remind them that it is the cell bodies of sensory nerves that are located within the "lump." "If you were to section through a ganglion, what color would it be?"

b. Just as one can predict the functional sensory and motor pathways by knowing the structural dorsal and ventral roots, the same is true concerning the tracts in the spinal cord. Ascending tracts are always sensory. Descending tracts are always motor. Point out that sensory information comes in the dorsal surface from the periphery, moves up to the brain, and then a motor response moves down from the brain and out of the ventral surface to the periphery.

c. Even though spinal reflexes are controlled entirely within the spinal cord, we become "aware" of them as ascending sensory tracts carry information about the reflex up to our brain where higher order functions occur.

Answers to End of Chapter Exercises

Level 1: Reviewing Facts and Terms

1. d	5. c	9. c	13. b
2. a	6. d	10. a	14. c
3. a	7. b	11. b	15. c
4. c	8. c	12. a	16. d

17. (1) dura mater: outermost covering
(2) arachnoid membrane: second meningeal layer
(3) pia mater: innermost meningeal layer

18. epineurium: surrounds spinal nerve; perineurium: surrounds fascicles (bundles of axons); endoneurium: surrounds individual axons

Level 2: Reviewing Concepts

19. d

20. The first cervical nerve exits anterior to vertebra C_1 (between the skull and vertebra); the last cervical nerve exits posterior to vertebra C_7 (between the last cervical vertebra and the first thoracic vertebra). There are thus 8 cervical nerves, but only 7 cervical vertebrae.

21. Since the cell bodies of spinal motor neurons are located in the anterior gray horns of the spinal cord, damage at that location would result in loss of motor control.

22. (1) walls of vertebral canal (2) epidural space (3) dura mater (4) subdural space (5) arachnoid membrane (6) subarachnoid space (7) pia mater (8) spinal cord

23. The subarachnoid space is filled with cerebrospinal fluid. The CSF acts as a shock absorber as well as a diffusion medium for dissolved gases, nutrients, chemical messengers, and waste products

24. (1) involvement of pools of interneurons
(2) intersegmental distribution
(3) involvement of reciprocal innervation
(4) motor response prolonged by reverberating circuits
(5) cooperation of reflexes to produce a coordinated, controlled response

25. (a) ventral ramus
(b) ventral ramus
(c) dorsal ramus
(d) ventral ramus

26. (a) cervical plexus
(b) lumbosacral plexus
(c) brachial plexus
(d) lumbosacral plexus

27. Transmission across a chemical synapse always involves a synaptic delay, but with only one synapse (monosynaptic), the delay between stimulus and response is minimized. In a polysynaptic reflex, the length of delay is proportional to the number of synapses involved.

28. (1) arrival of stimulus and activation of receptor
(2) activation of sensory neuron
(3) information processing
(4) activation of a motor neuron
(5) response by an effector (muscle or gland)

29. Since the ventral roots contain axons of motor neurons, those muscles controlled by the neurons of the root that is damaged would be paralyzed.

30. Stimulating the sensory neuron that innervates an extrafusal muscle fiber will increase the muscle tone.

31. The spinal cord ends at the level of L_2, thus there is little chance of damaging it below that level. A needle can be inserted through the meninges inferior to the conus medullaris into the subarachnoid space with minimal risk to the cauda equina.

Level 3: Critical Thinking/Application

32. Mary's sleeping position is likely causing compression of the median nerve.

33. Crutch paralysis results from compression of the radial nerve.

34. The nerve that is anesthetized in a woman during parturition is the genitofemoral nerve.

35. Ramon has a damaged femoral nerve. Since this nerve also supplies the sensory innervation of the skin on the anteromedial surface of the thigh and medial surfaces of the leg and foot, he may also experience numbness in these regions.

❑ Media Lab Instructor Notes

Web addresses often change. To avoid dead links, we are listing the keywords in parentheses next the to Web Explorations. Simply go to the Companion Website (http://www.prenhall.com/martini), select the Fifth Edition of Fundamentals of Anatomy and Physiology and search using the key word to locate the current address.

Animations (Website)

- Figure 13-1—Animation with toggle labels and pop-up inserts. Gross anatomy of adult spinal cord; suitable for self-study or lecture introduction of spinal cord.
- Figure 13-7—Animation in play / next format. Peripheral distribution of spinal nerves; suitable for step-wise discussion of organization of spinal cord during lecture, or self-study.
- Figure 13-13—Animation in play / pause format. Components of a reflex arc; suitable for lecture demonstration of reflex arc, or self-study.

Web Explorations (Overview)
Web Exploration 1 (**INJURY**)

- *Goal*—critical thinking, personal application
- *Description of page*—Neurotrauma law pages explanation of spinal cord injury and statistics
- *Expectations of student behavior*—read prose, taking notes on statistics
- *Instructor's role*—discuss spinal cord functional anatomy, statistical analyses and meanings
- *Special notes or further uses of exploration*—site well constructed with few distractions, e-mail allows for student contact with experts

Web Exploration 2 (**SPINAL QUIZ**)

- *Goal*—drill and practice, reinforcement of principles
- *Description of page*—hyper-card series of questions with BACK, NEXT format; answers explained in bottom window
- *Expectations of student behavior*—read and answer questions, writing notes on those missed
- *Instructor's role*—assist in terminology and question interpretation, provide navigational help to repeat
- *Special notes or further uses of exploration*—quiz provided for pharmacology med students; once a report is generated student must go back to Companion Website and re-enter to take the quiz again.

Additional Web Explorations
Should the two explorations found in the text not answer your needs, a third exploration is provided below. Your students do not have direct access to this exploration. You must provide them the address and information in the following paragraph.

Web Exploration 3
Estimated time for completion = 5 minutes

Chronic neck pain can be caused by a number of factors including whiplash, age and injury. What can be done for sufferers? Read the short article on **NECK PAIN** (http://www.cnn.com/HEALTH/9706/30/nfm.whiplash/) presented by CNN. Looking at the images in your text, what nerves do you suspect are involved in this procedure? Does this sound like something that you would have done on yourself? Why or why not? What complications can you imagine might be considered? If you wish, share your thoughts on this procedure with your classmates using the electronic communication tools on the Companion Website.

Web Exploration 3 (**NECK PAIN**)

- *Goal*—critical thinking, application of knowledge
- *Description of page*—easily read article presented on CNN in 1997; lots of external links and clicks available
- *Expectations of student behavior*—read information, study images in text, answer questions
- *Instructor's role*—explanation of spinal nerve functions, assist in anatomical orientation of procedure
- *Special notes or further uses of exploration*—many potentially distracting links to CNN stories; Guide to Whiplash link is worth looking at if student needs reference (click on "what is whiplash")

Topic Outline				A/V Resources				
Objectives	**Chapter 13** **The Spinal Cord and Spinal Nerves** (page 1 of 3)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
1a	**I. Introduction**							
	II. Gross Anatomy of the Spinal Cord	13-1	1a, 5a, 6a	●	●	●		
1b	A. Spinal Meninges	13-2a		●	●			●
	1. The Dura Mater	13-2ab	3a	●	●			
	2. The Arachnoid	13-2ab	3b	●	●			
	3. The Pia Mater	13-2ab,3	3c	●	●			
1c	B. Sectional Anatomy of the Spinal Cord	13-5		●	●			●
	1. Organization of Gray Matter	13-5a		●	●			
	2. Organization of White Matter	13-5a	6b	●	●			
1d	**III. Spinal Nerves**	13-6	3d	●	●			
2a	A. Peripheral Distribution of Spinal Nerves	13-7,8	5b	●	●	●		
	B. Nerve Plexuses	13-7,9	4a	●	●			●
	1. The Cervical Plexus	13-9,10		●	●			●
	2. The Brachial Plexus	13-9,11		●	●			●

Topic Outline				A/V Resources				
Objectives	**Chapter 13** **The Spinal Cord and Spinal Nerves** (page 2 of 3)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	3. The Lumbar and Sacral Plexuses	13-9,12		●	●			●
3a	**IV. An Introduction to Reflexes**							
	A. The Reflex Arc	13-13		●	●	●		
3b	B. Classification of Reflexes	13-14		●	●			
	1. Development of Reflexes							
	2. Processing Sites							
	3. Nature of the Response							
3d	4. Complexity of the Circuit	13-15		●	●			
	V. Spinal Reflexes		2a, 6c					
	A. Monosynaptic Reflexes							
	1. The Stretch Reflex	13-16,17,18		●	●			
	B. Polysynaptic Reflexes							
	1. The Tendon Reflex							
	2. Withdrawal Reflexes	13-19		●	●			

Topic Outline				A/V Resources				
Objectives	**Chapter 13** **The Spinal Cord and Spinal Nerves** (page 3 of 3)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	3. Crossed Extensor Reflexes	13-19		●	●			
3	**VI. Integration and Control of Spinal Reflexes**							
3c	A. Voluntary Movements and Reflex Motor Patterns			●				

CHAPTER 14

The Brain

Introduction

Recent research on the role of emotion in human behavior provides a fascinating prelude to the material in this chapter. Three recent books can provide you with many examples. The most general is *Emotional Intelligence* by Daniel Goleman (Bantam, 1995). This book was written by a correspondent from the *New York Times* and discusses the anatomy, physiology and applications of the new research on emotion. Antonio Damasio's book *Descartes' Error* (Grosset and Putnam, 1994) presents his research on the role of emotion in social and life decisions. He presents a fascinating and detailed discussion of the case of Phineas Gage, a workman who had an iron rod blown through his head in the 1800s. The image reconstruction of the skull with the rod makes a dramatic picture that will get the student's attention. The man survived and had unaltered intelligence but major personality changes. This leads in to many other interesting examples of the effects of prefrontal lobe damage. Lastly, Joseph LeDoux's book *The Emotional Brain* (Simon and Schuster, 1996) presents new discoveries about the fear system based in the amygdala. He also presents a critique of the concept of the limbic system.

Instructional Goals/Learning Objectives

1. To introduce the major regions of the brain and their important nuclei, tracts, and centers.

   a. *Name the major regions of the brain and describe their functions.*
   b. *Identify important structures within each region of the brain and explain their functions.*
   c. *Locate the motor, sensory, and association areas of the cerebral cortex and discuss their functions.*
   d. *Identify the cranial nerves and relate each pair of nerves to its principal destinations and functions.*
   e. *Discuss important cranial reflexes.*

2. To describe the formation and circulation of CSF. To emphasize its importance to normal CNS function and its use as a diagnostic tool.

   a. *Name the ventricles of the brain and describe their locations and the connections between them.*
   b. *Explain how the brain is protected and supported.*
   c. *Discuss the formation, circulation, and functions of the cerebrospinal fluid.*

3. To provide the background needed for Chapters 15-18.

❑ Teaching Strategies

1. Analogies

a. During discussion of major regions and landmarks, emphasize the organization of the cerebral hemispheres and the cerebellum linked to the brain stem by the diencephalon. Compare the structural and functional arrangement with a tree. The brain stem is analogous to the trunk of the tree. It provides basic structural and functional support for the rest of the tree. The cerebrum and cerebellum are the complex branches, diverging in many different directions. These offshoots have specialized structures that provide specialized functions for the tree, like the branches that produce leaves, flowers, and fruit in real trees. The diencephalon is the structural and functional junction of the branches and the trunk, the pinnacle of the trunk and the base of the branches, all in one. Substances entering the tree from the roots, flow up through the trunk to the diencephalon, where they are relayed out into various directions. Substances coming from the branches reverse the flow down the trunk.

b. Compare the diencephalon to a narrow hallway, whose walls nearly touch. The thalamus is a cluster of cell bodies (a center) located in the walls of the hallway. The hypothalamus is a center in the floor. At some point, there is a hole or recess in the floor, like a well, which leads to the pituitary.

c. Stress that the brain is hollow from the original embryonic hollow neural tube, but the ventricles are filled with cerebral spinal fluid produced by specialized ependymal cells. The ventricles are continuous with the spinal canal. To emphasize this point, as you describe the ventricles and their connecting foramina or ducts, have the students pretend that they are miniaturized and "walk them through" the ventricles (as was done with muscle tissue in Chapter 10).

You are standing in the lateral ventricle, a large irregularly-shaped cave that seems to have branches in several different directions. Projecting from the floor, like stalagmites, are the frilly choroid plexi that are responsible for the production of the cerebral spinal fluid. From a central area, the cave extends all the way forward into the frontal lobe, laterally into the temporal lobe, and dorsally into the occipital lobe. In the center you can see the narrow tube shaped interventricular foramen that leads to the third ventricle of the diencephalon. Because the third ventricle is medial and inferior to you, you must sit down and slide through the foramen, like sliding through the tube of a water slide. When you arrive in the third ventricle, you discover that it is so narrow that you must stand sideways, and even then the walls seem to press against you. You carefully work your way around so that you are perched on the cerebral peduncle and are facing posteriorly. Above you, like stalactites, there are more choroid plexi. You must be careful not to step backwards, because directly behind you is the opening to the infundibulum holding the pituitary. If you press your hands against the walls, you can feel the "lumps" of soma of the thalamus inside the walls. Directly in front of you, you see a mass of cells projecting out of one wall, extending across the third ventricle, and disappearing into the opposite wall, These are the gray cells of the intermediate mass that connect the left and right thalamic nuclei. You drop yourself, feet first, through the cerebral aqueduct, the corpora

quadrigemina above you and the cerebral peduncle beneath you. You discover that the fourth ventricle is oddly shaped, like a tent on its side. It also contains choroid plexi. If you remain facing posteriorly, you can wedge yourself in place by pressing your back against the wall where the pons is located and your feet against the opposite wall where the cerebellum is located. If you bend over you can see the cerebral spinal fluid flowing out through the medial and lateral apertures and down through the spinal canal.

d. As you view Figure 14-14, suggest that the thalamus is reminiscent of a compartmentalized switching station. As information passes through the station, it gets filed to the appropriate location so that it can be evaluated, filtered, and sent on its way.

2. Demonstrations

a. Show the corpus callosum from several different aspects, so that students can better visualize how broad it is. It is almost like an umbrella of fibers above the lateral ventricles.

b. Deeper cerebral structures tend to be more difficult for students to visualize, particularly in a three-dimensional sense. Use Figure 14-10 to help describe the location of the basal nuclei. Identify features already discussed to allow students to become oriented to the sectional view. (Indicate that the third ventricle and thalamus are slightly posterior to the placement of the frontal section.) Point out that the head of the caudate nucleus is superior to and more medial than the lentiform nucleus, but the tail is inferior to the lentiform and lateral to the head. Thus, the caudate nucleus curls around the lentiform nucleus like a lock of hair curling around someone's ear).

c. As with the cerebral nuclei, the location of the limbic system within the cerebral hemispheres is difficult for students to visualize. Use as many figures as possible illustrating the limbic system in a variety of different orientations. Relate new structures to the locations of already familiar ones. The pattern that the limbic system makes as it starts medially with the cingulate gyri and fornices and curls laterally to the hippocampi within the dentate gyri resembles the horns of a Big Horn ram.

d. As you describe the location of the left and right thalami, put your hands together, palms touching, to indicate how close the walls of the third ventricle are to each other. Describe the thalamic nuclei as being located within each hand. Grasp at ends of a pencil or piece of chalk between the second and third fingers of each hand to illustrate the location of the intermediate mass and the manner in which it "bridges" the ventricle.

e. One method to remember the five facial areas served by the facial nerve is to place the palm of the hand over the ear, and then spread the fingers to touch each of the five regions: temporal, zygomatic, buccal, mandibular, cervical.

3. Vocabulary Aids

a. The names of the five secondary regions of the brain make more sense if the meaning of the Greek word elements are given. Mention that the Greek word element "encephalo" means brain. Remind the students that the word element "telo" was used in describing "the end" phase of mitosis. In this context, the telencephalon is the top "end" of the CNS. The brain then "passes through" ("dia") the diencephalon to the brain stem. The brain stem is made up of the "middle" ("mes"), the "next" part "beyond" ("meta", also used in metacarpals), and the part that is continuous with the "marrow" ("myelo") of the spinal cord. You can also point out that the three regions of the brain stem are named in alphabetical order.

b. Associate the "S" in the word Sensory with the "S" in poStcentral gyrus.

c. Indicate that the name of the corpora quadrigemina means "four twin bodies." (Students often think the superior colliculi look like a little derriere.)

d. Before describing the function of the trochlear nerve, ask the students if they remember having heard the word "trochlear." Remind them of the trochlear surface of the humerus, so called because it resembled a "pulley." Given that information, ask them to deduce what extrinsic eye muscle this nerve controls.

e. As you discuss the abducens nerve, ask the students what word abducens reminds them of. Prompt them into saying "abduct." Ask them how the eyeball would move if it were being "abducted." Then ask them to deduce what extrinsic eye muscle this nerve controls.

f. Associate the word "vagus" (wanderer) with the word “Vagabond” (someone who drifts or wanders). The vagus nerve is the only cranial nerve that leaves the head region. Thus it wanders far from the other cranial nerves.

g. This chapter deals with brain anatomy, and there are few anatomical topics where you find as many conflicting interpretations and definitions. In many respects you pick a reference and stick with it, knowing that it will not agree with all other references or texts. Here are some major issues of disagreement that you may want to be aware of (From Ric Martini):

   i. Embryologists, comparative anatomists, and many neuroanatomy texts consider the term telencephalon as referring to the anterior portion of the prosencephalon that gives rise to the cerebrum, and that the cerebrum consists of the cerebral nuclei, the central white matter, and the neural cortex of the cerebral hemispheres. However, some neuroanatomists use the term cerebrum to refer to the entire cerebral hemispheres plus the diencephalon. For them, the telencephalon forms the cerebral hemispheres but only a portion of the cerebrum.

ii. The brain stem can be defined as the midbrain plus the medulla oblongata, or the diencephalon plus the medulla oblongata. Making matters even more complicated, some sources consider both to be valid, they use diencephalon plus medulla when discussing the embryonic brain, but switch to midbrain plus medulla when considering the adult brain. We felt it best to pick one and stick with it.

iii. The definition and usage of arachnoid granulations versus arachnoid villi remains in flux. We followed the usage in a neuroanatomy reference (deGroot): villi are individual, small elements that cannot be seen without a microscope; granulations are larger, macroscopically visible elements consisting of clusters of villi; they form in the adult and may become calcified late in life. Other sources feel that the term villi should remain valid whether they are individual and small, or clustered and large, as long as they are sites of CSF reabsorption. They reserve use of the term granulation for calcified structures no longer involved in CSF recycling.

iv. The term basal nuclei is sometimes used as synonymous with the cerebral nuclei, but more often this term is used to refer to a functional collection of nuclei involved with subconscious motor control. We have tried to avoid using the term at all, both because there is disagreement over its proper definition and because use of the word ganglia for structures inside the brain will only muddle the situation for students.

v. There is a lack of agreement concerning the "proper" names for several cranial nerves. Thus for CNVIII you find Vestibulocochlear, Acoustic, and Statoacoustic; for CNXI you have Accessory or Spinoaccessory or Spinal Accessory. We opted for vestibulocochlear because it made it easier to remember the names of the two branches of CNVIII.

4. Applications

a. Lipid soluble drugs can pass through the blood-brain barrier and affect CNS function.

b. The trigeminal is the nerve that is "deadened" with Novocaine at the dentist.

5. Common Student Misconceptions/Problems

a. Due to its complexity, the brain structure and function usually present somewhat of a challenge for most students. One of the most difficult aspects of brain anatomy for students to visualize is that the brain is a three-dimensional structure with cavities inside. The tendency is to think of it as a solid homogeneous mass. To help with this, allot some time to the embryological development of the brain so that students realize that the brain originates as a fluid-filled neural tube. Use Table 14.1 to illustrate the expansion from three primary vesicles to five regions of organization. Emphasize that the "hollowness" continues throughout development and eventually evolves into the four fluid filled ventricles.

b. Students see some "logic" to the location of the auditory cortex in the temporal lobe because of the spatial relationship to the ears, but the location of the visual cortex often seems odd. Point out that the optic fibers cross at the corpus callosum and extend back to areas in the occipital cortex.

c. Contradictory to the standard nomenclature, sometimes the cerebral or basal nuclei are referred to as the basal ganglia.

6. Lecture ideas

a. Using several pictures or overheads illustrating sectional views of the brain (frontal or horizontal), point out the patterns of gray and white matter. The names of the centers, nuclei, and tracts are not as important at this time as the visualization of the arrangement of gray and white matter. Point out that the pattern seen in the spinal cord was gray on the inside and white on the outside. The pattern in the cerebrum seems to be the reverse, white on the inside, gray on the outside making up the cortex. (Although there are nuclei deeper inside the cerebrum and other brain structures.) Remind the students that wherever they see a collection of soma, it indicates a region of interpretation and integration. The regions of white fibers are myelinated tracts leading to and from the centers.

b. Ask the students to trace a drop of blood from the choroid plexi in the lateral ventricles to the arachnoid granulations.

c. The gyri and sulci might look random but, with the exception of a few individual variations, the patterns are predictable.

d. It is the control of the cerebral nuclei that coordinates the unconscious swinging of our arms with our legs as we walk. Instead of swinging arms with opposite legs, as we unconsciously do when we walk, suggest to the students that they try swinging their right arm with their right leg and their left arm with their left leg. It is not difficult, but they must make a conscious effort with each step, and they better appreciate the level of "unconscious control" that the basal nuclei have.

e. If you are standing in a large area with lots of people around, and someone calls your name, or you spot someone familiar "from the corner of your eye," it is the reflex controlled within the corpora quadrigemina that enables you to turn your head in the direction of the sound or image.

f. Discussion of the cranial nerves can be done in order, I - XII, but it is sometimes easier for the students to tie the concepts together if the nerves are approached according to their primary function: I, II, VIII (primarily sensory); III, IV, VI, XI, XII (primarily motor); V, VII, IX, X (mixed). Stress that the sensory nerves receive afferent nerve impulses, motor nerves send efferent impulses, and the mixed nerves receive and send. As an aside, point out that of the twelve nerves, four are involved with the function of the eyes.

g. Describe all three intrinsic muscles of the eye. Underscore that the oculomotor nerve controls only the circular muscle of the iris and not the radial muscle. The students should anticipate continued discussion of this nerve when covering the PSNS of the ANS. (These muscles are visceral muscles.) Point out that the ciliary muscle and the circular muscle work together to change the shape of the lens and constrict the pupil when viewing objects at close range.

h. In addition to the mnemonic device given in the text for remembering the names of the cranial nerves in order, there is one that is frequently used to remember the primary functions of the cranial nerves: "Some Say Marry Money, But My Brother Says Bad Business Marry Money." (S = sensory, M = motor, B = both).

❑ Answers to End of Chapter Exercises

Level 1: Reviewing Facts and Terms

1.	i	12.	c	23.	c	34.	b
2.	n	13.	j	24.	l	35.	a
3.	f	14.	e	25.	b	36.	d
4.	a	15.	l	26.	d	37.	b
5.	k	16.	m	27.	j	38.	c
6.	q	17.	p	28.	f	39.	a
7.	o	18.	g	29.	g	40.	b
8.	d	19.	h	30.	i	41.	a
9.	r	20.	e	31.	a	42.	b
10.	b	21.	a	32.	c	43.	b
11.	h	22.	k	33.	d	44.	a

45. The cerebellum adjusts voluntary and involuntary motor activities on the basis of sensory information and stored memories of previous experiences.

46. The hypothalamus is the floor of the diencephalon. It contains centers involved with emotions, autonomic function, regulation of body temperature and hormone production; it is the primary link between the nervous and endocrine systems.

47. (1) cushioning delicate neural structures
(2) supporting the brain
(3) transporting nutrients, chemical messengers, and waste products

48. (1) In portions of the hypothalamus, the capillary endothelium is extremely permeable.
(2) Capillaries in the pineal gland are permeable. The pineal gland is located in the roof of the diencephalon.
(3) Capillaries at the choroid plexus are extremely permeable.

49. The limbic system includes nuclei and tracts along the border between the cerebrum and diencephalon. Its functions include: establishment of emotional states and related behavioral drives; linking the conscious, intellectual functions of the cerebral cortex with the unconscious and autonomic functions of the brain stem; facilitating memory storage and retrieval.

50.

I.	Olfactory N.	VII.	Facial N.
II.	Optic N.	VIII.	Vestibulocochlear N.
III.	Oculomotor N.	IX.	Glossopharyngeal N.
IV.	Trochlear N.	X.	Vagus N.
V.	Trigeminal N.	XI.	Accessory N.
VI.	Abducens N.	XII.	Hypoglossal N.

Level 2: Reviewing Concepts

51. d
52. a

53. The brain structure that resembles a sea horse is the hippocampus. It is found in the limbic system.

54. Stimulation of the feeding and thirst centers of the hypothalamus would produce sensations of hunger and thirst.

55. c

56. Parkinson's disease is associated with damage to the substantia nigra, which secretes dopamine.

57. The categorical hemisphere (left) contains the general interpretive, speech, and language-based skills centers. Reading, writing, speaking, performing analytical tasks and logical decision-making are dependent on processing done in the left hemisphere. The representational (right) hemisphere analyzes sensory information and relates the body to the sensory environment. Interpretive centers in this hemisphere permit the identification of familiar objects by touch, smell, sight, taste or feel. It is important in understanding three-dimensional relationships and in analyzing the emotional context of a conversation.

58. The clinical signs of life include respiratory and cardiac activity, which are controlled by centers in the medulla oblongata.

59. a) the large number of neurons and neuronal pools in the brain
    b) the complexity of interconnections between the neurons and neuronal pools in the brain

60. Wernicke's area (general interpreter area) and Broca's area (speech center) are major cortical areas involved in speech. Aphasia results in absence of or defects in speech and the inability to comprehend the language. Lesions in Wernicke's area are characterized by defective visual and auditory comprehension of language, repetition of spoken sentences and defective naming of objects. Lesions in Broca's area result in hesitant and distorted speech.

Level 3: Critical Thinking/Application

61. The sensory innervation of the nasal mucosa is by way of the maxillary branch of the trigeminal nerve (N V). Irritation of the nasal lining increases the frequency of action potentials along the maxillary branch of the trigeminal nerve to the semilunar ganglion. Second order neurons from the semilunar ganglion carry increased frequency of action potentials to centers in the mesencephalon (midbrain) that in turn excite the neurons of the reticular activating system (RAS). Increased activity by the RAS can raise the cerebrum back to consciousness.

62. The officer is testing the function of Bill's cerebellum. Many drugs, including alcohol, have pronounced effects on the function of the cerebellum. A person who is under the influence of alcohol is not able to properly anticipate the range and speed of limb movement because of slow processing and correction by the cerebellum. As a result, Bill has a difficult time performing simple tasks like walking a straight line or touching his finger to his nose.

63. The local anesthesia temporarily numbs portions of the hypoglossal nerve (N XII) that controls movements of the tongue. If Tyler tries to eat before the anesthetic wears off, there is a good possibility he will bite or otherwise injure his tongue without being aware of it. Since movements of the tongue manipulate food while chewing and help initiate a swallowing reflex, inability to properly move food within the mouth could result in his choking.

❑ Media Lab Instructor Notes

Web addresses often change. To avoid dead links, we are listing the keywords in parentheses next the to Web Explorations. Simply go to the Companion Website (http://www.prenhall.com/martini), select the Fifth Edition of Fundamentals of Anatomy and Physiology and search using the key word to locate the current address.

Animations (Website)

- Figure 14-5—Animation in play / pause format. Circulation of CSF; suitable for lecture enhancement to explain CSF formation and flow.
- Figure 14-8—Animation with roll-over colored areas. The cerebral hemispheres; suitable for lecture demonstration as discussing cerebrum, or for self-study.
- Figure 14-19—Animation in play / next format. Origins of the cranial nerves; suitable for lecture enhancement while discussing cranial nerve placement and function, or self-study.
-

Animations (CD-ROM)

- Rotating 3-dimensional cranial images corresponding to Figures 14-3 ventricles, 14-13 diencephalon and brain stem.

Web Explorations (Overview)
Web Exploration 1 (**PROBE**)

- *Goal*—experimentation, experiential learning
- *Description of page*—PBS-created site with easy navigation to history and experiment
- *Expectations of student behavior*—read prose, play with probe experiment
- *Instructor's role*—explain relevance to current neurophysiology, direct student attention to details of motion and probe location
- *Special notes or further uses of exploration*—requires Shockwave (link available on screen); good links to people and discoveries at end; potential for further student investigation

Web Exploration 2 (**STROKE**)

- *Goal*—critical thinking, expansion of knowledge base
- *Description of page*—general health information provided by Emory Medical School; interactive image of brain and cortex functions
- *Expectations of student behavior*—create table, interpretation of functions as related to symptoms
- *Instructor's role*—prepare students for interpretation, create blank table to complete?
- *Special notes or further uses of exploration*—links to other health-related sites provided by Emory; related site visited in MediaLab 8 carpal tunnel exploration.

Additional Web Explorations
Should the two explorations found in the text not answer your needs, a third exploration is provided below. Your students do not have direct access to this exploration. You must provide them the address and information in the following paragraph.

Web Exploration 3
Estimated time for completion = 7 minutes

Cranial nerves are traditionally tough to remember. Can you name the functions of each one? To help you study this, visit the resource on **CRANIAL NERVES** at this site (http://www.gwc.maricopa.edu/class/bio201/cn/cranqzr2.htm). On this page you will find an interactive quiz of cranial nerve function. Each time you choose the correct cranial nerve, a new function will appear. Play with this study aid until you feel confident you can list the functions of the nerves. Turn down the light on the monitor and try to list the 12 nerves and their functions without help. Could you do it? If not, turn the light back up and practice again! Create a poster of the cranial nerves and their functions to use as a study tool.

Web Exploration 3 (**CRANIAL NERVES**)
(http://www.gwc.maricopa.edu/class/bio201/cn/cranqzr2.htm)

- *Goal*—drill and practice, creation of study aid
- *Description of page*—short quiz screen with links to review pages and a quiz on cranial nerve names created by Dr. Crimando of GateWay Community College in Phoenix AZ.
- *Expectations of student behavior*—practice matching functions to nerves, writing / creating poster
- *Instructor's role*—discus cranial nerves; assist students who need review to use on-line resources
- *Special notes or further uses of exploration*—easy to use site; clicking on bio 201 homepage links to interesting A&P explorations, as will going to the review site – great bookmark site for self-study

Objectives	Topic Outline: Chapter 14 The Brain and Cranial Nerves (page 1 of 4)	Figures	Strategies	A/V Resources: Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	I. Introduction		5a					
1a	**II. An Introduction to the Organization of the Brain**							
1b	A. A Preview of Major Regions and Landmarks	14-1,2	1ab, 6a	●	●			●
	B. Embryology of the Brain		3a					
2a	C. Ventricles of the Brain	14-3	1c	●	●	●		
2b	**III. Protection and Support of the Brain**							
	A. The Cranial Meninges	14-4		●	●			●
	1. Functions of the Cranial Meninges	14-4		●	●			
2c	B. Cerebrospinal Fluid							
	1. The Formation of CSF	14-5a		●	●	●		●
	2. Circulation of CSF	14-5	6b	●	●	●		●
	C. The Blood Supply to the Brain		4a					
	1. The Blood-Brain Barrier							
	IV. The Cerebrum	14-1bd		●	●			●

Topic Outline				A/V Resources				
Objectives	**Chapter 14** **The Brain and Cranial Nerves** (page 2 of 4)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	A. The Cerebral Cortex	14-1		●	●			
	1. Cerebral Landmarks and Lobes	14-1a	6c	●	●			
	2. The White Matter of the Cerebrum	14-7	2a	●	●			
	3. Motor and Sensory Areas of the Cortex	14-8	3b, 5b	●	●	●		●
	4. Association Areas	14-8a		●	●	●		
	5. Integrative Centers	14-8bc		●	●	●		
	6. Hemispheric Lateralization	14-9		●	●			
	B. The Cerebral Nuclei	14-10	2b, 5c	●	●			
	1. Functions of the Cerebral Nuclei		6d					
	V. The Limbic System	14-10cd,11,12	2c	●	●			
	VI. The Diencephalon	14-10cd,13		●		●		
	A. The Thalamus	14-12a,14	2d	●	●			
	1. Functions of the Thalamic Nuclei	14-14		●	●			
	B. The Hypothalamus	14-12a,15		●	●			

Objectives	TOPIC OUTLINE **Chapter 14** **The Brain and Cranial Nerves** (page 3 of 4)	Figures	Strategies	A/V RESOURCES: Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	1. Functions of the Hypothalmus	14-15a		●	●			
	VII. The Mesencephalon	14-13,16	3c, 6e	●	●			
	VIII. The Cerebellum	14-17		●	●			●
	IX. The Pons	14-13,18a		●	●			
	X. The Medulla Oblongata	14-13,18b		●	●			
1d	**XI. Cranial Nerves**		6f					
	1. The Olfactory Nerves (N I)	14-19,20		●	●	●		●
	2. The Optic Nerves (N II)	14-19,21		●	●	●		●
	3. The Oculomotor Nerves (N III)	14-22	6g	●	●			●
	4. The Trochlear Nerves (N IV)	14-22	3d	●	●			●
	5. The Abducens Nerves (N VI)	14-22	4e	●	●			●
	6. The Trigeminal Nerves (N V)	14-23	3e	●	●			●
	7. The Facial Nerves (N VII)	14-24	2e	●	●			●
	8. The Vestibulocochlear Nerves (N VIII)	14-25		●	●			●

TOPIC OUTLINE

Objectives	Chapter 14 The Brain and Cranial Nerves (page 4 of 4)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	9. The Glossopharyngeal Nerves (N IX)	14-26		●	●			●
	10. The Vagus Nerves (N X)	14-27	3f	●	●			●
	11. The Accessory Nerves (N XI)	14-28		●	●			●
	12. The Hypoglossal Nerves (N XII)	14-28	6h	●	●			●
	A. Summary of Cranial Nerve Branches and Functions							

(Transparency, Still-CD, Anim-CD, Video Tutor and Quiz Art are grouped under A/V RESOURCES.)

CHAPTER 15

Integrative Functions

Introduction

One of my favorite integrative functions to discuss with students is sleep. We know so little about it yet it consumes nearly one third of our lives. This topic is fun because it can be discussed from an evolutionary perspective as well as from a physiological perspective. Many of these topics are discussed in a nicely written little book *Sleep Thieves* by Stanley Coren (Simon and Schuster, 1996). Why do we sleep? This question has not yet been answered but it is a good opportunity to discuss scientific hypotheses (see Chapter 4 of Coren). Chapter 6 provides an interesting diary of a professor who tried to train himself to survive on less than six hours of sleep. The chapter on sleep apnea (Ondine's Curse) is also interesting. The book contains lots of practical information about sleep. I recommend putting it on reserve.

Instructional Goals/Learning Objectives

1. To describe the higher-order functions of the CNS, and to relate the functions to specific pathways and centers when possible. To emphasize the complexity of the system, and to note areas where our information is sketchy at best.

   a. *Explain how memories are created, stored, and recalled.*
   b. *Distinguish between the levels of consciousness and unconsciousness, and identify the characteristics of brain activity associated with the different levels of sleep.*
   c. *Describe the alterations in brain function produced by administered drugs.*
   d. *Summarize the effects of aging on the nervous system.*

2. To describe the principal sensory and motor pathways.

   a. *Describe the major descending and ascending tracts of the spinal cord.*
   b. *Describe the levels of information processing involved in motor control.*
   c. *To show how the pyramidal and extrapyramidal systems perform in an integrated fashion in the course of everyday movements.*
   d. *Discuss how the brain integrates sensory information and coordinates responses.*
   e. *Explain how we can distinguish between sensations that originate in different areas of the body.*

3. To return to the levels of organization theme both in terms of processing levels and with reference to the performance of cyclic or patterned behaviors, such as walking.

❑ Teaching Strategies

1. Analogies

a. Compare the inhibitory effect on excitatory motor neuron activity to a radio that is switched on, but the volume is turned all the way down, the electrical activity is there, but the sound is being inhibited. If the inhibition of the volume was to stop, we would hear the radio.

b. The different neurotransmitters and the responses they elicit can be compared to seasonings and herbs used in cooking. Foods take on entirely new "personalities" depending upon the type and amount of seasoning or herb used. Sometimes the differences in herbs are more subtle and maybe even complementary; other times they can completely change the character of the food. For example, if you use cinnamon and sugar when making bread, the result is a sweet and delicate taste that goes well with fruit and coffee. If you substitute allspice for the cinnamon, the taste changes slightly, but the end result is similar. The use of garlic and oregano would result in a bread that was equally delicious, but it would so radically change the characteristic of the bread that it would no longer go well with fruit. It would much better compliment spaghetti or lasagna. Of course, using the appropriate seasoning in the correct proportions is the key to the behavior of a skilled chef.

2. Demonstrations

3. Vocabulary Aids

a. When discussing nociceptors, note that the word element "nocco" is the same as in the word "noxious."

b. When discussing the fasciculus cuneatus, remind the students of the use of the same word element when learning the "wedge-shaped" metatarsals, the cuneiforms.

4. Applications

a. Amyotrophic lateral sclerosis (ALS) is sometimes referred to as Lou Gehrig's Disease, named after the famous New York Yankees pitcher who died of ALS.

b. If you are not afraid of dating yourself, you can ask the students if they are familiar with the music of Woody Guthrie, the musician who died of Huntington's Chorea. Mention that with the techniques of biotechnology and the mapping of the human genome, the likelihood of getting Huntington's can be predicted years before the onset of the disease.

c. Alzheimer's disease is difficult to accurately diagnose in its early stages, and can be positively confirmed only if a postmortem reveals the characteristic plaques and neurofibrillary tangles.

d. One of the problems with "natural" drugs, particularly if they come in the form of teas, herbs, infusions, and dehydrated powders, is that there is no reliable way of determining how pure the drug is or what the dosage might be.

e. It might be appropriate to discuss the concept of drug tolerance as it relates to down-regulation and up-regulation of receptor sites on postsynaptic cell membranes.

f. The fact that morphine can mimic the activity of endorphins, because it is structurally similar is yet another good example of a structure/function relationship.

5. Common Student Misconceptions/Problems

6. Lecture ideas

a. After explaining the nomenclature of the sensory and motor pathways, quiz the students by giving them names of pathways and asking them to determine: 1) if it is ascending or descending, 2) if it is sensory or motor, and 3) what destination or origination is indicated in the name.

b. Although temperature receptors are sensitive to temperature changes, the temperature receptors that detect heat are different than those that detect cold.

c. Have the students repeat from memory the concept illustrated in Figure 15-1. Quiz them by asking questions such as, "A first-order neuron is located where?," "It carries information from where to where?," etc. Understanding the relay from first order to second-order to third-order, and the anatomical locations of those relays is a crucial first step to comprehending the material to follow. Emphasize that cross-over occurs in either the first order or second-order neuron.

d. Point out that since the dorsal root is the sensory pathway of the PNS, it makes sense that the dorsally located fasciculi would be the sensory tracts within the CNS. Analogously, point out that, with the exception of the rubrospinal and lateral corticospinal tracts, the descending motor pathways occur in the ventral region of the spinal cord. This structural arrangement corresponds to the functional placement of the ventral roots, which carry efferent messages to the PNS.

e. Note that the four cranial nerves that feed sensory information into the medial lemniscus are the same four nerves that are classified as "mixed."

f. Stress that sensory information carried along the spinocerebellar pathway is headed for the cerebellum; consequently, we are not aware of the sensations. We become conscious of the sensory input only if it reaches the cerebrum.

g. Point out that ACh is a neurotransmitter found in both the CNS and the PNS. It is usually stimulatory. Remind the students that ACh is the same neurotransmitting substance used in the neuromuscular junction to stimulate skeletal muscle activity.

❑ Answers to End of Chapter Exercises

Level 1: Reviewing Facts and Terms

1. a
2. d
3. c
4. d

5. (1) Nociceptors-variety of stimuli associated with tissue damage.
(2) Thermoreceptors-respond to change in temperature.
(3) Mechanoreceptors-stimulated or inhibited by physical distortion, contact or pressure.
(4) Chemoreceptors-monitor the chemical composition of body fluids and respond to the presence of specific molecules.

6. (1) Posterior column pathway- provides conscious sensations of highly localized ("fine") touch, pressure, vibration and proprioception.
(2) Spinothalamic pathway-provides conscious sensations of poorly localized ("crude") touch, pressure, pain, and temperature.
(3) Spinocerebellar pathway-carries proprioceptive information concerning the position of skeletal muscles, tendons and joints to the cerebellum.

7. (1) corticobulbar tracts
(2) lateral corticospinal tracts
(3) anterior corticospinal tracts

8. (1) vestibulospinal pathway
(2) tectospinal pathway
(3) reticulospinal pathway

9. (1) The cerebellum integrates proprioceptive sensations with visual information from the eyes and equilibrium-related sensations from the inner ear.
(2) The cerebellum adjusts the activities of the voluntary and involuntary motor centers, based on sensory information and the stored memories of previous experiences.

10. (1) The number of neurons in the cerebral cortex continues to increase until at least age 1.
(2) The brain as a whole grows in size and complexity until at least age 4.
(3) Myelination of CNS neurons continues at least until puberty, reducing the delay between stimulus and response and improving motor control.

11. (1) The functions are performed by neurons of the cerebral cortex, and involve complex interactions between areas of the cortex and between the cerebral cortex and other parts of the brain.
(2) They involve both conscious and unconscious information processing.
(3) Their functions are subject to modification and adjustment over time.

12. increased neurotransmitter release; facilitation of synapses; formation of additional synaptic connections

13. During non-REM sleep, the entire body relaxes and activity at the cerebral cortex is at a minimum. Heart rate, blood pressure, respiratory rate and energy utilization decline. During REM sleep, active dreaming occurs, accompanied by alterations in blood pressure and respiratory rates. Muscle tone decreases markedly and there is less response to outside stimuli.

14. reduction in brain volume and weight; reduction in the number of neurons; decrease in blood flow to the brain; changes in the synaptic organization; intracellular and extracellular changes in CNS neurons

Level 2: Reviewing Concepts

15. d

16. The sensory neuron that delivers the sensations to the CNS is called a first-order neuron. Within the CNS, the axon of the first-order neuron synapses on an interneuron known as a second-order neuron. The second-order neuron, located in the spinal cord or brain stem, synapses on a third-order neuron in the thalamus. The axons of third-order neurons synapse on neurons of the primary sensory cortex of the cerebral hemispheres.

17. The somatic nervous system (SNS), which is under voluntary control, controls the contractions of skeletal muscles. The autonomic nervous (ANS) or visceral motor system, controls visceral effectors, such as smooth and cardiac muscles, glands and fat cells.

18. A motor homunculus, a mapped-out area of the primary motor cortex, provides an indication of the degree of fine motor control available. A sensory homunculus indicates the degree of sensitivity of peripheral sensory receptors.

19. Injury to the primary motor cortex affects the ability to exert fine control over motor units. Gross movements are still possible, however, since they are controlled by the cerebral nuclei using the reticulospinal or rubrospinal tracts. Thus, walking and other voluntary and involuntary movements can still be performed, but the movements are imprecise and awkward.

20. Muscle tone is controlled by the red nuclei of the mesencephalon, whose axons descend in the rubrospinal tract. The motor neurons of the red nucleus are controlled by neurons in the cerebral nuclei, cerebellum, and reticular formation. Stimulation of the motor neurons increases muscle tone, whereas inhibition decreases muscle tone.

21. A CVA (cerebrovascular accident or stroke) is more likely to be devastating if it occurs in the left hemisphere, since in most people this is the site of the general interpretive and speech centers. This is the hemisphere which is responsible for language-based skills, analytical tasks and logical decision making. If a CVA occurred in the right hemisphere, it could affect the patient's ability to analyze sensory information and relate the body to the sensory environment.

Level 3: Critical Thinking/Application

22. The tumor is most likely located adjacent to the corticobulbar tracts. The axons of these tracts carry action potentials to motor nuclei of the cranial nerves that control eye muscles and facial expression.

23. You would expect to observe some degree of paralysis on the left side of Doris's body, relative to the amount of motor cortex deprived of blood. You might also observe some degree of memory loss, changes of mood, and some impairment of planning abilities.

24. The data suggest that the drug is mimicking the effects of the neurotransmitter serotonin. The areas of the brain that are being affected include the occipital lobe (visual hallucinations, color enhancement), the temporal lobe (auditory hallucinations), and the limbic system (increased sexual appetite).

❑ Media Lab Instructor Notes

Web addresses often change. To avoid dead links, we are listing the keywords in parentheses next the to Web Explorations. Simply go to the Companion Website (http://www.prenhall.com/martini), select the Fifth Edition of Fundamentals of Anatomy and Physiology and search using the key word to locate the current address.

Animations (Website)

- Figure 15-3—Animation in play / next format. The posterior column and spinothalamic pathways; suitable for lecture enhancement during spinothalamic pathway discussion, self-study tool after lecture.
- Figure 15-7—Animation in play / next format. The pyramidal system; suitable for lecture demonstration of pyramidal pathways, self-study tool after presentation.
- Figure 15-8—Animation with pop-up labels and color coded regions. Centers of somatic motor control; suitable for lecture enhancement while discussing motor control regions of brain, or self-study.

Web Explorations (Overview)
Web Exploration 1 (**PROPRIOCEPTION**)

- *Goal*—experimentation, experiential learning
- *Description of page*—Exploratorium site with easy prose and image links to additional experiments
- *Expectations of student behavior*—read prose and perform simple demonstrations
- *Instructor's role*—monitor student participation in activities, focus student thought processes
- *Special notes or further uses of exploration*—requires pencil and paper, good experiments to combine class data and discuss statistics and analysis

Web Exploration 2 (**BREAKTHROUGHS**)

- *Goal*—historical perspective, ethical questioning
- *Description of page*—referenced article with left and right side bar links presented by Brain.com
- *Expectations of student behavior*—read prose, reflect on societal meaning of physiology research
- *Instructor's role*—prompt students to relate information to current health care, standard of life
- *Special notes or further uses of exploration*—related articles also scientifically sound; internal links remain within Brain.com global site; good discussion creation site linking knowledge to life

Additional Web Explorations
Should the two explorations found in the text not answer your needs, a third exploration is provided below. Your students do not have direct access to this exploration. You must provide them the address and information in the following paragraph.

Web Exploration 3
Estimated time for completion = 7 minutes

Neurotransmitters in the CNS regulate everything from thought patterns to behavior. What happens to this biochemical regulation when we add outside chemicals? One chemical that is familiar to us either through personal experience or popular media coverage is alcohol. What does this chemical do to the integrative abilities of the brain? Is there any biochemical reasoning behind the "cures" for hangovers? To answer these questions, read the information on **ALCOHOL** at (http://www.brain.com/about/static_123099_feature-alcohol.htm) and outline the facts presented. Do some of the cures actually work? What is the biochemical basis for the symptoms of drunkenness and hangover? What changes will you make in your personal choices concerning alcohol after reading this article?

Web Exploration 3 (**ALCOHOL**)

- *Goal*—critical thinking, application of knowledge
- *Description of page*—long, referenced article with left and right side bar links presented by Brain.com
- *Expectations of student behavior*—read article, perhaps click links to review, take notes and apply to personal experience
- *Instructor's role*—provide organic chemistry information on alcohol, acetaldehyde, etc.
- *Special notes or further uses of exploration*—related articles also scientifically sound; internal links remain within Brain.com global site; good discussion creation site linking knowledge to life

Topic Outline				A/V Resources				
Objectives	**Chapter 15** **Integrative Functions** (page 1 of 2)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	I. Introduction	15-1		●	●			
2d	**II. Somatic Sensory and Motor Pathways**		6a					
2a	A. Sensory Pathways							
2e	1. Receptors for the General Senses		3a, 6b					
	2. The Organization of Sensory Pathways	15-2	6c	●	●			●
	3. The Posterior Column Pathway	15-3a	3b, 6de	●	●			
	4. The Spinothalamic Pathway	15-3bc, 4		●	●	●		
	5. The Spinocerebellar Pathways	15-5	6f	●	●			
2a	B. Motor Pathways and Motor Control	15-6		●	●			
2c	1. The Corticospinal Pathway	15-7		●	●	●		
2c	2. The Medial and Lateral Pathways	14-16		●	●			
2b	3. The Cerebral Nuclei and Cerebellum							
	4. Levels of Processing and Motor Control	15-8		●	●	●		
	III. Monitoring Brain Activity: The Electroencephalogram	15-9			●			

Topic Outline				A/V Resources				
Objectives	**Chapter 15** **Integrative Functions** (page 2 of 2)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	IV. Higher-Order Functions							
1a	A. Memory	15-10		●	●			
	1. Brain Regions Involved in Memory Consolidation and Access	14-11		●	●			
	2. Cellular Mechanisms of Memory Formation and Storage							
1b	B. Consciousness							
	1. Sleep	15-11			●			
	2. Arousal	15-12			●			
1c	**V. Brain Chemistry and Behavior**		1b, 4bdef					
	A. Personality and Other Mysteries							
1d	**VI. Aging and the Nervous System**							
	A. Age-Related Anatomical and Functional Changes							
	B. Alzheimer's Disease		4c					

CHAPTER 16

The Autonomic Nervous System

Introduction

Probably the most interesting application of this material is in pharmacology. Many of the drugs we use to treat disease work via the autonomic nervous system. The students will be familiar with many of these from their parents or other relatives who use the drugs. You might start with a list of these common drugs and ask the students what symptom or disease they are used to treat. If you have a relatively large class this isn't too hard to do. Next, ask the students how these drugs work. They will be interested to find out that all of them work on a common system. A discussion of the development of these drugs in terms of increased specificity is also useful. This will help motivate the students to learn about the different classes of adrenergic and cholinergic receptors. Drug treatment of hypertension is a particularly detailed area that has many interesting examples. You can follow the development of drugs from nonspecific adrenergic blockers to specific β subtype blockers. The benefit from reduced side effects is a good discussion point and allows you to integrate information about various sympathetic functions.

Instructional Goals/Learning Objectives

1. To understand the structure, function and control of the autonomic nervous system and its branches.

   a. *Compare the autonomic nervous system with other divisions of the nervous system.*
   b. *Discuss the relationship between the divisions of the autonomic nervous system and the significance of dual innervation.*
   c. *Describe the hierarchy of interacting levels of control in the autonomic nervous system.*
   d. *Contrast the structures and functions of the sympathetic and parasympathetic divisions of the autonomic nervous system.*
   e. *Explain the importance of autonomic tone.*

2. To understand the pharmacology of the autonomic nervous system and how this knowledge is used clinically.

   a. *Describe the mechanisms of neurotransmitter release in the autonomic nervous system.*
   b. *Compare the effects of the various autonomic neurotransmitters on target organs and tissues.*
   c. *Describe the effects of mimetic drugs on autonomic nervous system activities.*

❑ Teaching Strategies

1. Analogies

a. The ganglion of the sympathetic chain is like a switching station in a train yard. When the preganglionic message gets to the station, the "switch master" will continue the message down the postganglionic railroad track via the gray ramus if the message is for visceral effectors in the body wall, or he will switch the message to the autonomic tracks if the message is for a deeper visceral organ.

2. Demonstrations

a. Read the warning label of a well-known brand of ephedrine or pseudoephedrine. Ask the students why the use of the medication is contraindicated for people who have high blood pressure. Why is "dry mouth" one of the side effects?

3. Vocabulary Aids

a. Students are sometimes puzzled by the use of the term adrenergic to describe synapses that release NE or E. Explain that while the term cholinergic clearly sounds like the description of synapses that release ACh, those that release NE or E are classified as adrenergic, because NE and E were once referred to as noradrenaline or adrenalin.

4. Applications

a. It is important to impress upon students entering the health care profession the significance of the autonomic nervous system when it comes to its role in maintaining homeostasis. Since most disease states result as either a cause or a consequence of a disruption in the normal ANS reflex patterns, understanding the mechanisms of this "silent" control center is a crucial first step to comprehending pathology. Additionally, almost every aspect of pharmacology and pharmacotherapy has some impact on the ANS, whether it be directly or indirectly, intentionally or as an undesirable side effect. The entire system is such a delicately balanced, complicated web of integrated processes that altering even one small element can create a rippling effect with staggering consequences.

b. Ask the students to explain why it is suggested that you wait one or two hours after eating before going swimming. Point out the concurrent and contradictory demands that would be required of the SNS and the PSNS.

c. During aerobic exercise people will often feel for their carotid pulse in order to calculate their working heart rate. Palpation of the area can cause manual stimulation of the vagus nerve, which lies directly adjacent to the common carotid artery. Stimulation of the vagus nerve will result in decreased heart rate, right at a time when there is a demand for an increased heart rate! The result can be loss of consciousness.

d. The pupillary reflex is frequently used as a quick evaluative tool during a neurological exam, especially if an injury to the CNS is suspected.

e. Bella Donna ("Beautiful Woman") is a plant once used for medicinal purposes. It was so named because it stimulates the SNS control of the radial muscle causing dilation of the pupils (as they are during sexual arousal), a characteristic that was considered to enhance the beauty of the eyes.

f. Many students have heard of the use of "beta blockers." Ask them to explain what specific beta receptors are being blocked, what the effect would be, and why it is a medication taken by people with high blood pressure.

g. Scopolamine is sometimes referred to as the sea-sick patch.

5. Common Student Misconceptions/Problems

a. As you study Figure 16-5, indicate that "somatic structures" refer to visceral effectors in the skin and body surface (the somatic region), NOT to skeletal muscle.

b. Make sure that it is understood that, since both divisions of the ANS are active to some degree all the time (autonomic tone), drugs can enhance the activity of one division by either stimulating it directly or inhibiting the activity of the other division. For example, a sympathomimetic drug can mimic sympathetic activity due to stimulation of the SNS OR due to blocking of the PSNS. Likewise, a parasympathomimetic drug's action will be to either stimulate the PSNS OR to block the SNS.

6. Lecture ideas

a. The basic organization of the nervous system should be fairly well ingrained at this point, but the attention to the detailed "trees" in the previous two or three chapters, may necessitate the need to step back and review the "forest." Students benefit from frequent recycling of information during the ongoing (and usually arduous) process of accumulating facts; it provides for them a new paradigm on an established perspective, so that they see that rather than just an accumulation of individual, unrelated facts, there is an integrated "big picture." Present a schematic drawing of the organization (using Figure 16-1), indicating the afferent and efferent relationship between the CNS and the PNS. Remind the students that the effectors of the somatic nervous system are skeletal muscles; whereas, the effectors of the ANS (or visceral nervous system) are smooth muscle, cardiac muscle and glands. The somatic nervous system has only one efferent neuron that will directly stimulate the skeletal muscle. The autonomic nervous system has two efferent neurons, a preganglionic neuron whose cell body is in the CNS, and a postganglionic neuron whose cell body is in a ganglion in the PNS. The result of activating the ANS neurons can be stimulatory or inhibitory. Point out that the name "autonomic" implies "self-governing"; but, while the ANS is automatic, it is anatomically part of the CNS and PNS, and therefore, it influences and is influenced by the physiology of the organ systems of the body.

b. Stress the overall pattern of the sympathetic nervous system. Encourage the students to associate the signs and symptoms of sympathetic stimulation with the circumstances that might bring about such signs and symptoms. Emphasize the anatomical positioning of the SNS. Indicate that "thoracolumbar" refers to the location of the sympathetic nerves branching off of the spinal cord. "Fight or Flight" is the traditional expression used to characterize the response of the SNS; a more up-to-date expression (and one that amuses the students) might be "Kick Butt or Haul Ass."

c. As with the SNS, stress the overall pattern of the parasympathetic nervous system. Encourage the students to associate the signs and symptoms of parasympathetic stimulation with the circumstances that might bring about such signs and symptoms. Emphasize the anatomical positioning of the PSNS. Contrast it to the location of the SNS. Point out that the four cranial nerves (III, VII, IX, and X) comprise the "cranio" portion of the craniosacral division. The Greek word element "para" can mean "along side" or "against"; the PSNS works along side the SNS, but appears to have effects that are against or opposite the SNS. (This does not mean that they are always antagonistic). "Rest and Digest" (as opposed to "rest and repose") is a more suggestive phrase that can be used to describe the characteristics of the PSNS.

d. Using Table 16-2, carefully compare the general structural and functional characteristics of the SNS and the PSNS. Stress the neurotransmitting substances of each, and whether they are excitatory or inhibitory. The structural differences of the pre and postganglionic fibers, the difference in the neurotransmitters, and the degree of divergence allow the SNS to have a mass or generalized effect, while the PSNS has a much more localized effect.

   Once the innervation patterns of each division have been discussed, quiz the students over the material. Describe various scenarios, reading a newspaper, watching a Freddie Kruger movie, studying A&P, being kissed by your grandmother, being kissed by your girlfriend or boyfriend, etc., and ask them to determine which of the two divisions would be more active. Have them work in pairs and try to describe the structural characteristics and the overall function of each division.

   Suggest that the students develop a running summary sheet comparing the two divisions of the ANS. They should compare anatomical location, general effects, patterns of divergence, relative length and placement of pre and postganglionic fibers, neurotransmitters, membrane receptors and responses, etc. Tables -16-2 and 16-3 provide a similar summary, but retention will be enhanced if the students create their own study sheet as they progress through the chapter.

e. Compare the structure and function of the white and gray rami communicantes of the pre and postganglionic fibers. (Remind the students that the preganglionic fibers are white, because they are myelinated; the postganglionic fibers are gray, because they are unmyelinated).

f. The preganglionic innervation of the adrenal medulla represents the "bridge" between the SNS and the endocrine system. Most students know that adrenaline (epinephrine) is released during times of stress; they could probably describe the feeling of an "adrenaline rush." It should appear logical to them that the SNS, the division of the ANS that is activated during stressful situations, has a direct connection to the adrenal medulla.

g. Ask the students to explain the following: "Two postganglionic sympathetic nerves in the ANS are stimulated. Both are adrenergic. How come one stimulates an effector organ and the other inhibits an effector organ?" For example, how come sympathetic stimulation of the cardiac muscle causes it to increase in activity, while sympathetic stimulation of the smooth muscle of the bronchioles causes it to relax and dilate? Allow time for them to ponder this apparent contradiction. As they begin to guess the possibilities, try to manipulate their conjectures to include the receptors of the postsynaptic membrane. Emphasize that the manner in which an effector responds depends not only upon which neurotransmitter is released, but how that neurotransmitter sends its signal through the membrane to alter cellular activity. Review the direct and second messenger mechanisms. The mechanism and whether the end result will be stimulatory or inhibitory is dependent upon the type of receptor on the target cell's membrane.

❑ Answers to End of Chapter Exercises

Level 1: Reviewing facts and terms

1. a
2. d
3. c
4. b
5. a
6. c
7. c
8. a
9. d

10. The sympathetic preganglionic fibers emerge from the thoracolumbar area, (T_1 through L_2) of the spinal cord. The parasympathetic fibers emerge from the brain stem and the sacral region of the spinal cord (craniosacral).

11. Preganglionic neuron (T_5-L_2) - collateral ganglia - postganglionic fibers - visceral effector in abdominopelvic cavity.

12. (1) celiac ganglion (2) superior mesenteric ganglion (3) inferior mesenteric ganglion

13. (1) the release of norepinephrine at specific locations. (2) the secretion of epinephrine (and modest amounts of norepinephrine into general circulation.

14. An adrenergic synaptic terminal releases norepinephrine when stimulated. At a cholinergic synapse, the presynaptic membrane releases acetylcholine upon stimulation.

15. cranial nerves III, VII, IX, and X.

16. (1) ciliary ganglion (2) sphenopalatine ganglion (3) submandibular ganglion (4) otic ganglion

17. sympathetic/parasympathetic (a) cardiac plexus: heart rate-increase/decrease; heart strength-increase/decrease; blood pressure-increase/decrease (b) pulmonary plexus: respiratory passegways-dilate/constrict (c) esophageal plexus: respiratory rate-increase/decrease (d) celiac plexus: digestion - inhibit/stimulate (e) inferior mesenteric plexus: digestion-inhibit/stimulate (f) hypogastric plexus: defecation-inhibit/stimulate; urination-inhibit/stimulate; sexual organs-secretion/erection.

18. receptor - sensory neuron - interneuron or visceral motor neuron - two visceral motor neurons

19. Processing centers in the medulla oblongata coordinate complex sympathetic and parasympathetic reflexes. These medullary centers are in turn subject to regulation by the hypothalamus. Centers in the posterior and lateral hypothalamus are concerned with the coordination and regulation of sympathetic function, and portions of the anterior and medial hypothalamus control the parasympathetic division.

Level 2: Reviewing Concepts

20. d
21. a

22.

	Sympathetic	Parasympathetic
(a) mental alertness	increased	decreased
(b) metabolic rate	increased	decreased
(c) digestive/urinary function	inhibited	stimulated
(d) use of energy reserves	stimulated	inhibited
(e) respiratory rate	increased	decreased
(f) heart rate/blood pressure	increased	decreased
(g) sweat glands	stimulated	inhibited

23. Damage to the ventral roots of cervical spinal nerves will produce voluntary muscle paralysis on the affected side, but leave sympathetic function intact because the preganglionic fibers innervating the cervical ganglia originate in the white rami of thoracic segments, which are undamaged.

24. Preganglionic fibers entering the adrenal gland proceed to the adrenal medulla, where they synapse on neuroendocrine cells that release the neurotransmitters norepinephrine and epinephrine into the general circulation.

25. Stimulation of alpha receptors activates enzymes on the inside of the cell membrane. Stimulation of beta receptors in organs and tissues triggers changes in the metabolic activity of the target cell. The beta receptor causes formation of a second messenger that activates or deactivates key enzymes.

26. The effects of parasympathetic stimulation are short-lived because most of the acetylcholine released is inactivated by acetylcholinesterase within the synapse. Any acetylcholine diffusing into the surrounding tissues will be inactivated by the enzyme tissue cholinesterase.

27. If autonomic motor neurons maintain a background level of activity at all times, they can either increase or decrease their activity, providing a range of control options.

28. Due to stimulation of sympathetic nervous activity, you would experience: an increased respiratory rate, speeding up gas exchange; an increase in vasoconstriction of peripheral blood vessels, causing an increase in blood pressure; an increase in heart rate and force of contraction, causing an increased rate of blood delivery; an increase in the release of glucose into the blood, increasing the nutrient supply for energy metabolism

Level 3: Critical Thinking/Clinical Application

29. Stress-induced stomach ulcers are due to excessive sympathetic stimulation. The sympathetic division causes vasoconstriction of vessels supplying the digestive organs, causing an almost total shutdown of blood supply to the stomach. Lack of blood leads to tissue death and necrosis, which causes the ulcers.

30. You would want to use a beta-blocker, since stimulation of beta-1-receptors increases heart rate. By blocking these receptors, parasympathetic influence will predominate and the heart rate will slow down.

31. Epinephrine would be most helpful in alleviating the symptoms of the allergic reaction. Epinephrine helps to reduce inflammation and relaxes the smooth muscle of the airways, making it easier for Billy to breathe.

32. The molecule is mimicking the action of norepinephrine, by binding to alpha-1 receptors.

❑ Media Lab Instructor Notes

Web addresses often change. To avoid dead links, we are listing the keywords in parentheses next the to Web Explorations. Simply go to the Companion Website (http://www.prenhall.com/martini), select the Fifth Edition of Fundamentals of Anatomy and Physiology and search using the key word to locate the current address.

<u>**Media Resources on the Student's CD-ROM and Companion Website**</u>

Animations (Website)

- Figure 16-1—Animation in play / next format. Organization of somatic and autonomic nervous systems; suitable for self-study tool or lecture enhancement during ANS introduction.
- Figure 16-5—Animation in play / next format. The sympathetic division; suitable for lecture demonstration of sympathetic innervations, self-study tool after presentation.
- Figure 16-9—Animation in play / next format. Distribution of parasympathetic innervation; suitable for lecture demonstration of parasympathetic innervations, self-study tool after presentation.

Web Explorations (Overview)
<u>Web Exploration 1</u> **(NICOTINE)**

- *Goal*—critical thinking, concept review
- *Description of page*—left hand side bar with tangetial links, information gathered by Dr Pugh Med School of Ohio
- *Expectations of student behavior*—read three sequential pages, take notes, reflect on personal choices
- *Instructor's role*—clarify organic chemistry, guide students through links, model debate procedure
- *Special notes or further uses of exploration*—informal presentation of excellent science; further links on site also good resources—better for instructor bookmark that student as difficult to relate to study

<u>Web Exploration 2</u> **(ADD)**

- *Goal*—application of knowledge, critical thinking
- *Description of page*—authors from U of Toronto; well documented article; no links
- *Expectations of student behavior*—read article, reflect on information and relate to self
- *Instructor's role*—prompt students to relate information to personal behavior, assist with technical terminology
- *Special notes or further uses of exploration*—difficult to understand on first reading; may want to summarize portions for students.

Additional Web Explorations
Should the two explorations found in the text not answer your needs, a third exploration is provided below. Your students do not have direct access to this exploration. You must provide them the address and information in the following paragraph.

<u>Web Exploration 3</u>
Estimated time for completion = 5 minutes

The autonomic nervous system can seem overwhelming if not studied in an organized manner. One way to

organize your notes is to create a simple outline from which to build. Read the **ANS REVIEW** at this site (http://faculty.washington.edu/chudler/auto.html) to receive a concise description of the autonomic nervous system, complete with a table of 12 organs and the actions created via sympathetic or parasympathetic stimulation. Re-create that table for your notes, adding the type of receptor responsible for each action. Include other organs as they are described in the text. You may wish to share your information through the creation of a visual display, using either a computer program similar to PowerPoint or traditional poster board.

Web Exploration 3 (**ANS REVIEW**)

- *Goal*—drill and practice, review and condense
- *Description of page*—ANS lecture page with active links to other lectures from Washington U.
- *Expectations of student behavior*—review ANS functions, clarify notes, create study aid
- *Instructor's role*—provide feedback on additional information for table; assist in presentation preparation
- *Special notes or further uses of exploration*—good student bookmark for self-directed review.

TOPIC OUTLINE				A/V RESOURCES				
Objectives	**Chapter 16** **The Autonomic Nervous System** (page 1 of 3)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	I. Introduction		4a					
1a	**II. An Overview of the ANS**	16-1	6a	●	●	●		
	A. Divisions of the ANS							
	1. Innervation Patterns in the ANS	16-2	6d	●	●			
1d	**III. The Sympathetic Division**	16-3,4	6b	●	●			
	A. The Sympathetic Chain	13-6a, 16-4		●	●			●
	1. Anatomy of the Sympathetic Chain	16-5	1a, 5a, 63	●	●	●		
	B. Collateral Ganglia	16-4b,5		●	●			
	C. The Adrenal Medullae	16-4c, 5		●	●			
	D. Sympathetic Activation							
2e	E. Neurotransmitters and Sympathetic Function	16-6	2a, 3a, 4ef	●	●			
	1. Sympathetic Stimulation and the Release of NE and E							
	2. Sympathetic Stimulation and the Release of ACh and NO							

Topic Outline				A/V Resources				
Objectives	**Chapter 16** **The Autonomic Nervous System** (page 2 of 3)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	F. Summary: The Sympathetic Division							
1d	**IV. The Parasympathetic Division**	16-7		●	●			
	A. Organization and Anatomy of the Parasympathetic Division	16-8		●	●	●		
	B. General Functions of the Parasympathetic Division		4b					
2a	C. Parasympathetic Activation and Neurotransmitter Release							
	1. Membrane Receptors and Responses							
	D. Summary: The Parasympathetic Division							
1b	**V. Interaction of the Sympathetic and Parasympathetic Divisions**							
	A. Anatomy of Dual Innervation	16-9	4c	●	●			
2c	B. A Comparison of the Sympathetic and Parasympathetic Divisions	16-10		●	●			●

TOPIC OUTLINE				A/V RESOURCES				
Objectives	**Chapter 16** **The Autonomic Nervous System** (page 3 of 3)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
1e	C. Autonomic Tone		5b					
1c	**VI. Integration and Control of Autonomic Functions**	15-8	4de	●	●			
	A. Visceral Reflexes	16-11		●	●			
	B. Higher Levels of Autonomic Control	16-12		●	●			
	1. The Integration of SNS and ANS Activities	16-13		●	●			

CHAPTER 17

Sensory Function

Introduction

There is a very interesting sensory anomaly you can use as a fun hook to get students discussing general principles of sensory function. The condition is known as synaesthesia. Synaesthesia occurs in about 1 out of every 25,000 people and involves a mixing of sensory perceptions. Synaesthesics report hearing color, seeing sounds, and many other weird combinations. These individuals suffer from no pathology and live normal productive lives. Many synaesthesics have been successful artists. The mechanism of synaesthesia is not yet known. It is fun to have the students come up with their own hypotheses about what could be going on. This is a natural place to discuss the concept of labeled lines and how a mixing of the labeled lines might lead to synaesthesia. A good discussion of this topic is found in chapter 5 of *Mapping the Mind,* a wonderful new book on the brain by Rita Carter (University of California Press, 1998).

Instructional Goals/Learning Objectives

1. To introduce the principles of sensory coding and receptor function.

   a. Distinguish between the general and special senses.
   b. Explain how receptors respond to specific stimuli and how the organization of a receptor affects its sensitivity.

2. To detail histological/functional classifications of general and special sensory receptors.

   a. Identify the receptors for the general senses and describe how they function.

3. To describe the structure and function of each special sense organ, relating its anatomical organization to its particular sensitivities.

   a. Describe the sensory organ of smell, and trace the olfactory pathways to their destinations in the brain.
   b. Describe the sensory organs of taste and trace the gustatory pathways to their destinations in the brain.
   c. Describe the internal structures of the eye and explain their functions.
   d. Explain how we are able to distinguish colors and perceive depth.
   e. Explain how light is converted into nerve impulses and trace the visual pathways to their destinations in the brain.
   f. Describe the structures of the outer and middle ear, and explain how they function.
   g. Describe the parts of the inner ear and their roles in the process of hearing.
   h. Trace the pathways for the sensations of equilibrium and hearing to their respective destinations in the brain.

4. To demonstrate how abnormalities of structure or function can produce important clinical problems.

❑ Teaching Strategies

1. Analogies

a. To illustrate the role of transducer that the sensory receptor plays, provide the following scenario. During a general assembly at the United Nations, there are many different representatives from many different countries speaking many different languages. To prevent it from becoming the modern day Tower of Babel, there are specially trained translators who can translate one language into another almost instantaneously. Thus, if you could speak only French, anything that was being said, no matter what the language, would be translated into French so that you could understand. The nervous system speaks only one language, that of electrical currents (action potentials), which is a different language than the thousands of stimuli that bombard our bodies (inside and out) every second. It is a sensory receptor's job to translate the language of the stimulus into the language of the nervous system. In so doing, the receptor acts as a transducer, translating one form of energy into another. Whether the stimulus is in the form of sound waves, light waves, pain, vibration, proprioception, a chemical, temperature, or pressure change, the receptor will convert that stimulus into an action potential. There may be specialized structures associated with the receptor to amplify or protect, but within every sensory receptor, there is always a structure whose exclusive function is to act as a translator. You can illustrate receptor specificity by emphasizing that each translator is capable of transducing only one language. Thus, there must be a different translator for each language.

b. Describe the three steps of the transduction process with a football analogy. The quarterback (receptor) receives the ball from the center (stimulus) at the beginning of the play. He then can initiate one of two plays: 1) pass (receptor potential) the ball to the halfback (sensory neuron), who will in turn pass (generator potential) the ball to the tightend, who carries (action potential) it across the goal line (CNS); OR 2) pass the ball directly to the tightend (in which case the quarterback is acting as the receptor potential and the generator potential).

c. Describe the cochlear chambers as a spiral staircase in zero gravity. The staircase is the scala media. You can climb up the staircase along the scala vestibuli, but when you reach the top, instead of turning around and coming back down the way you ascended, you walk over the top step and descend along the under surface of the staircase (the scala tympani).

d. When describing the movement of the perilymph from the oval window to the round window during the hearing process, ask the students to imagine standing at the end of a long pool in which the water is very still. If they were to start a wave at one end (the stapes at the oval window), the pressure from that wave would cause it to continue down the length of the pool until it hit the other end (the round window).

2. Demonstrations

a. Illustrate how the conjunctiva forms a continuous epithelial membrane from the inner surface of the upper eyelid, along the surface of the eye, to the inner surface of the lower eyelid.

b. The combined effect of parasympathetic stimulation of the oculomotor nerve (III) will constrict the pupillary opening and contract the ciliary body for close vision. During sympathetic stimulation the pupil dilates and stimulation of the ciliary body is turned off, so it relaxes for far vision. This explains why we are unable to focus on close and distant objects at the same time. This point can be illustrated if you ask the students to hold their index finger about 10-12 inches in front of their nose. If they focus on their finger, the board in the front of the room is blurred. If they focus on the board, their finger is blurred. If there is enough difference between the near and far points, a student sitting next to them can observe the changing of the pupil diameter.

c. Frequently, there are one or two individuals in the class who are colorblind. If they do not object, try to obtain some color blindness eye charts and have them report what they see as compared to the rest of the class.

d. Illustrate the process of adaptation by asking the students to plug up their left ear very tightly. Play a recorded humming or ringing sound (similar to one heard from a tuning fork). After 45 seconds of listening with the right ear, have them unplug their left ear. The sound should appear as if it got louder as a result of adaptation in the right ear and lack of adaptation in the left ear. The room must be very quiet for this demonstration. It works better if you use a stethoscope on a single individual and have them pinch one of the tubes to simulate plugging the ear.

3. Vocabulary Aids

a. In order to learn the individual receptors and what they do, make the following associations:

1. Midas Touch-Meissner's corpuscles (for light touch)
2. The "P" in pressure-Pacinian corpuscles
3. A ruffle can be stretched-Ruffini corpuscles (for stretch)

b. Associate the "C," in Cone with the "C" in Color. Point out that the three types of cones detect red, green, and blue, not the primary colors red, yellow, and blue as one might suspect.

c. When someone is "nearsighted," they can only "sight the near." That is, if I am myopic, I see things close to Me. When someone is "farsighted," they can only "sight the far." If I am hyperopic, then I see things close to He.

4. Applications

a. If a stimulus occurs outside of a receptive field, it is not perceived. When references are made to certain parts of our body being "particularly sensitive," it is because the receptive fields of those parts are very close together. The more vulnerable the area, the more likely it is to have many overlapping receptive fields in order to detect noxious stimuli.

b. Individual differences in the ability to tolerate pain may have something to do with individual differences in the release and activity of neuromodulators.

c. The fact that temperature sensations are conducted along the same labeled lines as pain sensations explains why temperature changes can be perceived as painful.

d. Inform the students that they can impress their friends by referring to the "caruncular secretions" in the corner of their eyes as opposed to the more mundane terminology of "sleep," "sandman dust," or "eye buggers."

e. Individuals with Dell's Palsy, a condition affecting cranial nerve VII discussed in Chapter 14, must use artificial tears to keep the eye on the affected side lubricated since they do not blink.

f. Ask the students why, after an eye examination, the ophthalmologist gives you those nifty looking sun glasses. Why is it difficult to read?

g. Anyone who has applied for a driver's license has taken a visual acuity test. The chart of letters that gradually decrease in size is called a Snellen Eye Chart. Point out that the fraction used to describe visual acuity as a result of a Snellen Eye Test always includes the individual's results in the numerator as compared to the rest of the population in the denominator.

h. The pharyngotympanic (Eustachian) tubes are nearly horizontal in children, but become more vertical as we grow. This accounts for the frequent occurrence of middle ear infections in children which they seem to "outgrow" as they age. Some children require the insertion of small tubes into the eardrum to keep the middle ear "aerated" and inhibit the growth of bacteria.

i. It is a spinning dancer's or ice skater's ability to fix their focus on one point with only brief interruptions as they complete their spin, that enables them to recover without feeling dizzy and appearing as if they were at the end of the Crack-the-Whip chain.

j. Benign paroxysmal positional vertigo is a temporary condition that causes vertigo and nystagmus whenever the head is turned in a certain position. The cause is sometimes difficult to determine, but one of the diagnostic procedures is to observe nystagmus whenever the subject changes body or head position. It is similar to the feeling one gets when they "get up too quickly," only the effect lasts longer and is more severe.

k. Artificial ossicles are sometimes used to replace those that have become ossified and are interfering with the conduction process.

5. Common Student Misconceptions/Problems

a. Take care that the students perceive the difference between touch and pressure. One example that can help with the distinction is to remind students of the experience of getting Novocaine at the dentist (if they don't object to being reminded of the experience). Novocaine deadens the sensation of touch (as well as pain), so that a light touch of the teeth, gums, lips, or cheeks is undetected. However, pressing against those same surfaces can be perceived as pressure.

b. Baroreceptors are sometimes referred to as stretch receptors. Hence, the type of pressure that they detect is a pressure associated with the stretching of hollow organs.

c. Students often think that the lingual papillae they see on their tongue are the taste buds. Clarify that the taste buds are recessed in pits around the papillae.

d. Students are often surprised to discover that tears form at the superior, lateral portion of the orbit; most think they form at the medial canthus. Emphasize that tear production at the superior fornix enables the lacrimal fluid to flow with gravity and enhances and bathing of the entire conjunctival surface. Have the students trace a tear drop by listing the structures in the proper sequence from the site of production to the passage into the inferior meatus of the nasal cavity.

e. Make careful distinction between the anterior and posterior chambers and the anterior cavity. Clearly state, "There is an anterior chamber within the anterior cavity and a posterior chamber within the anterior cavity."

f. Most diagrams of the eye show a cross sectional view. Students sometimes lose sight of (forgive the pun) the fact that the ciliary body, ciliary processes, and suspensory ligaments form a complete circle around the eye.

g. The process of accommodation can be confusing to students, because there is a tendency to incorrectly reverse the effect of the ciliary muscle on the shape of the lens. Explain the process in a step-by-step manner as you diagram each step:

1. Because of the elastic tissue envelope that surrounds the lens, its natural shape is almost spherical; hence, its convex surface bends light at a sharp angle needed for viewing things close to you. If you wanted to view an object further away, the lens needs to become flatter, so it does not bend light as much.
2. The suspensory ligaments connect the lens to the ciliary muscle all the way around the lens. Pulling on the ligaments, pulls on the lens, making it flatter or less curved. Releasing the ligaments, stops the pull on the lens, making it fatter or more curved. Imagine the leather cords used to sew the rawhide surface of a drum to the surrounding frame. If you tighten the cords, the drum becomes more taut. If you loosen the cords, the drum becomes loose.
3. The ciliary muscle works like a sphincter muscle. When it contracts, the

diameter of the opening around the lens becomes smaller. When it relaxes, the diameter of the opening around the lens becomes wider. Imagine the cords of the drum attached to a frame that operates like a draw-string pouch. As the metal bands of the frame are tightened, the diameter of the frame becomes smaller. As the metal bands of the frame are loosened, the diameter of the frame becomes wider. (Use your hands to illustrate the opening and closing action).

4. Since the suspensory ligaments are attached to the lens at one end and the ciliary muscle at the other, the action of the ciliary muscle will affect the shape of the lens. As the muscle contracts, the ligaments loosen, relieving the tension on the lens, and it becomes fatter. As the diameter of the draw-string frame becomes smaller, the cords attached to the drum loosen, so that the drum becomes loose. As the muscle relaxes, the ligaments become taut, increasing the tension on the lens, and it becomes flatter. As the diameter of the draw-string frame becomes wider, the cords attached to the drum tighten, so that the drum becomes tight.
5. Use the following rhyme to help describe:

   a) the distance of the viewed object
   b) the condition of the ciliary body
   c) the effect on the suspensory ligaments
   d) the shape of the lens

Remote -	Relax -	Pull -	Flat
Close -	Contract -	Loose -	Fat

h. Using Figure 17-24, carefully explain the pathway of stimulation and relay to the visual cortex in the occipital lobes. Stress that each occipital lobe receives information from both eyes because of the crossing fibers at the optic chiasma.

6. Lecture ideas

a. As with other structures studied, general receptors can be classified according to their structure (i.e., location) or their function (i.e., the nature of stimulus they detect). Stress that these categories are not mutually exclusive. For example, mechanoreceptors can be either exteroceptors or interoceptors.

b. Another example to illustrate the adaptation of thermoreceptors is our ability to swim in a pool of cold water once we have "gotten used to it." Pose the following: If you were preparing a bath for a patient, why should you avoid frequent "testing" of the water to see if it is a comfortable temperature?

c. Point out that olfactory receptors represent one of the few locations of bipolar neurons. The retina is another rare location for bipolar neurons.

d. Olfactory sensations are tied very closely to long-term memory, and are sometimes considered some of the most vivid and persistent memories we have.

e. The pupillary muscles were referred to as the circular and radial muscles during the discussion of the cranial nerves. Remind the students that the circular muscle (pupillary constrictor) is controlled by parasympathetic fibers of cranial nerve III. The radial muscle (pupillary dilator) is controlled by sympathetic fibers. These muscles work antagonistically.

f. Observe that the retina covers only the posterior two-thirds of the eye; it does not pass completely around the eye like the other tunics.

g. Since the photoreceptors are deeper than the layers sandwiched on top, light must pass through all the layers before it is detected by the photoreceptors. Stimulation is relayed, layer-by-layer, up from the photoreceptors.

h. Have students trace a drop of aqueous humor by listing the structures in proper sequence from the site of production to reabsorption into the venous system.

i. The cornea, the aqueous humor, the lens, and the vitreous body all refract light as it passes through the eye, but the lens is the only structure capable of changing its shape to control the focal distance and influence the focal point.

❑ Answers to End of Chapter Exercises

Level 1: Reviewing Facts and Terms

1. b
2. d
3. d
4. a
5. b
6. a
7. d
8. b
9. b
10. a
11. d
12. d
13. a
14. c
15. c
16. b
17. c
18. d
19. d
20. b
21. d
22. d
23. c

24. (1) An arriving stimulus alters the transmembrane potential of the receptor membrane. (2) The receptor potential directly or indirectly affects a sensory neuron. (3) Action potentials travel to the CNS along an afferent fiber.

25. (1) tactile receptors (2) baroreceptors (3) proprioceptors

26. (1) free nerve endings-sensitive to touch and pressure (2) root hair plexus-monitor distortions and movements across the body surface (3) tactile discs-fine touch and pressure receptors (4) tactile corpuscles-fine touch and pressure sensation (5) lamellated corpuscles-most sensitive to pulsing or vibrating stimuli (deep pressure) (6) Ruffini corpuscles-sensitive to pressure and distortion of the skin

27. Axons leaving the olfactory epithelium collect into twenty or more bundles that penetrate the cribriform plate of the ethmoid bone to reach the olfactory bulbs of the cerebrum. Axons leaving the olfactory bulb travel along the olfactory tract to reach the olfactory cortex, the hypothalamus, and portions of the limbic system.

28. (1) filiform papillae (2) fungiform papillae (3) circumvallate papillae

29. (a) the sclera and the cornea (b) the fibrous tunic:
    1. provides mechanical support and some degree of physical protection
    2. serves as an attachment site for the extrinsic eye muscles
    3. contains structures that assist in the focusing process

30. The iris, ciliary body, and the choroid make up the vascular tunic of the eye.

31. A nerve impulse passes along the optic nerve, portions of which cross those of the other eye at the optic chiasma. The impulse may cross at the chiasma to the opposite side of the brain (along the optic tract). The impulse may terminate at nuclei that control eye reflexes, or continue to the thalamus. Upon reaching the thalamus, the impulse is transmitted to another neuron, which conducts it to the occipital lobe of the cerebral cortex.

32. (1) malleus, (2) incus, (3) stapes, which transmit a mechanical vibration from the tympanic membrane to the oval window. As it is transmitted, the vibration is amplified.

33. (1) Sound waves arrive at the tympanic membrane. (2) Movement of the tympanic membrane causes displacement of the auditory ossicles. (3) Movement of the stapes at the oval window establishes pressure waves in the perilymph of the vestibular duct. (4) The pressure waves distort the basilar membrane on their way to the round window of the tympanic duct. (5) Vibration of the basilar membrane causes vibration of hair cells against the tectorial membrane (6) Information concerning the region and intensity of stimulation is relayed to the CNS over the cochlear branch of N VIII.

Level 2: Reviewing Concepts

34. c
35. c

36. The general senses include somatic and visceral sensation. The special senses are those whose receptors are confined to the head.

37. Regardless of the type of stimulus, the CNS receives the sensory information in the form of action potentials.

38. Sensory coding (the pattern of action potentials in the afferent fibers) provides information about the strength, duration, variation, and movement of the stimulus.

39. The olfactory system has extensive limbic connections, indicating its effect on memories and emotions.

40. Infection of eyelash sebaceous glands or Meibomian glands generally results in the formation of a painful swelling called a sty.

41. A visual acuity of 20/15 means that Jane can discriminate images at a distance of 20 feet, whereas someone with "normal" vision must be 5 feet closer (15 ft.) in order to see the same details. Jane's visual acuity is better than the acuity of someone with 20/20 vision.

Level 3: Critical Thinking/Clinical Applications

42. As you turn to look at your friend, the medial rectus muscles would contract, directing your gaze more medially. In addition, the pupil would constrict and the lens would become more spherical.

43. Sally is apparently nearsighted (myopic) and needs convex lenses to correct the condition.

44. The noise from the fireworks has transferred so much energy to the endolymph in the cochlea, that it continues to move for a long time. As long as the endolymph is moving, it will vibrate the tectorial membrane and stimulate the hair cells. This produces the "ringing" sensation that Millie perceives. She finds it difficult to hear conversation because the vibrations associated with normal conversation are not strong enough to overcome the currents already moving through the endolymph, making the vibrations difficult to discern against the background "noise."

45. The rapid descent in the elevator causes the maculae in the saccule of the vestibule to slide upwards, producing the sensation of downward vertical motion. When the elevator abruptly stops, the maculae do not. Because of their relatively large inertia, it takes a few seconds for them to come to rest in the normal position. As long as the maculae are displaced, the perception of movement will remain.

46. As long as such people receive visual clues, they can maintain their position relatively well. When they close their eyes, the brain must rely solely on proprioceptive information and information from the static equilibrium centers (saccule and utricle). If there is a problem with the saccules or utricles, the brain does not receive sufficient information to maintain balance, and the person begins to sway. The movement of the arms towards the side of the impaired receptors is due to the deficit of information arriving from that side of the body.

❑ Media Lab Instructor Notes

Web addresses often change. To avoid dead links, we are listing the keywords in parentheses next the to Web Explorations. Simply go to the Companion Website (http://www.prenhall.com/martini), select the Fifth Edition of Fundamentals of Anatomy and Physiology and search using the key word to locate the current address.

Animations (Website)

- Figure 17- 16—Animation in play / next format. Photoreception; suitable for lecture demonstration of photoreceptor action, self-study tool after presentation.
- Figure 17- 25—Animation in play / next format. The vestibular complex; suitable for self-study review or lecture enhancement while discussing equilibrium.
- Figure 17- 30—Animation in play / next format. Sound and hearing; suitable for lecture demonstration of pathway of sound, or self-study after presentation.

Animations (CD-ROM)

- Rotating 3-dimensional sensory organ images corresponding to Figures 17-6 eye, 17-22 Whole ear, and 17-24 inner ear.

Web Explorations (Overview)
Web Exploration 1 **(VISION)**

- *Goal*—exploration of knowledge, critical thinking
- *Description of page*—Eyenet page with links on right sidebar to other areas; links within text
- *Expectations of student behavior*—read three sequential pages, take notes, reflect on personal choice
- *Instructor's role*—guide students through links, discuss non-surgical options, clarify images / prose
- *Special notes or further uses of exploration*—helpful to bring in current news articles on these procedures—advertisements, local practitioners serve as resources

Web Exploration 2 **(IMPLANT)**

- *Goal*—application of knowledge, critical thinking
- *Description of page*—Harvard Mahoney Neuroscience Inst. Informational page, no distractions
- *Expectations of student behavior*—read article, grasp 3 dimensional view of implant
- *Instructor's role*—assist in visualization, provide review of basic functioning
- *Special notes or further uses of exploration*—good joining of science and emotions; site can be model for writing assignment based on personal experience with techno-medicine.

Additional Web Explorations
Should the two explorations found in the text not answer your needs, a third exploration is provided below. Your students do not have direct access to this exploration. You must provide them the address and information in the following paragraph.

Web Exploration 3
Estimated time for completion = 5 minutes

You have learned that the inner ear functions in maintaining balance as well as hearing. What happens when the semicircular canals are not formed properly? Read this **VERTIGO** article at this site (http://www.bme.jhu.edu/labs/chb/disorders/scd/scd.html), comparing the images to those in your text. Why does this explanation of noise-induced vertigo make sense? Explain the functioning of the normal semicircular canals by drawing the structures involved and depicting the direction of fluid flow. Overlay your drawing with a tracing of the damaged structures as described. Indicate how this damage leads to vertigo when exposed to loud noises by again depicting the direction of fluid flow.

Web Exploration 3 (**VERTIGO**)

- *Goal*—review, visualize and hypothesize
- *Description of page*—informational sheet from Johns Hopkins School of Med (no links)
- *Expectations of student behavior*—read, draw inner ear and reconstruct described defect
- *Instructor's role*—assist in visualization of damage, define terms, interpret images
- *Special notes or further uses of exploration*—video loads slowly, but is interesting.

Topic Outline				A/V Resources				
Objectives	**Chapter 17** **Sensory Function** (page 1 of 4)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
1a	**I. Introduction**		1a					
1b	**II. Receptors and Receptor Function**							
	A. The Detection of Stimuli	17-1	4a	●	●			
	B. The Interpretation of Sensory Information							
	C. Central Processing and Adaptation							
2a	**III. The General Senses**		6a					
	A. Nociceptors	17-2a	4b	●	●			
	B. Thermoreceptors		4c, 6b					
	C. Mechanoreceptors							
	1. Tactile Receptors	17-2	3a, 5a	●	●			●
	2. Baroreceptors		5b					
	3. Proprioceptors							
	D. Chemoreceptors							
3a	**IV. Olfaction**	17-3		●	●			

Topic Outline				A/V Resources				
Objectives	**Chapter 17 Sensory Function** (page 2 of 4)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	A. Olfactory Receptors	17-3b	6c	●	●			
	B. Olfactory Pathways	17-3	6d	●	●			
	C. Olfactory Discrimination			●				
	D. Aging and Olfactory Sensitivity							
3b	**V. Gustation**	17-4a		●	●			
	A. Taste Receptors	17-4bc	5c					
	B. Gustatory Pathways							
	C. Gustatory Discrimination	17-4a		●	●			
	D. Aging of Gustatory Sensitivity							
	VI. Vision							
	A. Accessory Structures of the Eye	17-5a		●	●			
	1. Eyelids	17-5	2a, 4d	●	●			
	2. The Lacrimal Apparatus	17-5b,6a	4e, 5d	●	●			●
3c	B. The Eye	17-5b,6bc	5e	●	●	●	●	●

Objectives	Topic Outline: Chapter 17 Sensory Function (page 3 of 4)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	1. The Fibrous Tunic	17-5a, 6		●	●			
	2. The Vascular Tunic	17-6, 7	5f, 6e	●	●			
	3. The Neural Tunic	17-6bc, 8, 9	3b, 6fg	●	●			●
	4. The Chambers of the Eye	17-10	6h	●	●			
3d	5. The Lens	17-[10-14]	2b,3c,4fg,5a,6	●	●			
	C. Visual Physiology		2c				●	
	1. Anatomy of Rods and Cones	17-15		●	●			
	2. Photoreception	17-16, 17		●	●	●		
	3. Color Vision	17-18			●			
	4. Light and Dark Adaptation							
3e	D. The Visual Pathway		5h				●	
	1. Processing by the Retina	17-20		●	●			
	2. Central Processing of Visual Information	17-21		●	●			
	VII. Equilibrium and Hearing							

A/V Resources: Transparency, Still-CD, Anim-CD, Video Tutor, Quiz Art

	Topic Outline			A/V Resources				
Objectives	**Chapter 17** **Sensory Function** (page 4 of 4)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
3f	A. Anatomy of the Ear	17-22		●	●	●	●	●
	1. The External Ear	17-22		●	●			●
	2. The Middle Ear	17-22, 23	4h	●	●			●
	3. The Inner Ear	17-22, 24a		●	●	●		●
	4. Receptor Function in the Inner Ear	17-24b		●	●			
	B. Equilibrium							
	1. The Semicircular Ducts	17-25ab, 24a		●	●	●		
	2. The Utricle and Saccule	17-25ade		●	●			
3h	3. Pathways for Equilibrium Sensations	17-26	4ij	●	●			
3g	C. Hearing							
	1. The Cochlear Duct	17-27, 28	1c	●	●			●
	2. An Introduction to Sound	17-29			●			
	3. The Hearing Process	17-30	1d	●	●			
3h	4. Auditory Pathways	17-31		●	●	●		
	5. Auditory Sensitivity							

CHAPTER 18

The Endocrine System

❑ Introduction

A good example of hormone physiology and pathology that could be used to introduce this section to your students can be found in a pair of articles in *Scientific American Science and Medicine*. The first article by Sarrel, Lufkin, Oursler, and Keefe (July/August 1994) describes a number of aspects of estrogen function not normally discussed, especially at the introductory level. The authors present the role of estrogen on arteries and its cardioprotective function; the role of estrogen in bone function and the problem of postmenopausal osteoporosis; and finally actions of estrogen on the brain. This is all used as a backdrop for discussing estrogen replacement therapy. The second article by Osborne, Elledge and Fuqua (January/February 1996) discuss the role of estrogen in breast cancer and its treatment by tamoxifen. This article is useful in that it discusses many details of the estrogen receptor.

❑ Instructional Goals/Learning Objectives

1. To give the student an appreciation of the general organization of the endocrine system.

   a. *Compare the endocrine and nervous systems.*
   b. *Compare the cellular component of the endocrine system with those of other tissues and systems.*
   c. *Describe how endocrine organs are controlled.*

2. To introduce the major hormones, their tissues of origin, their targets, and their mechanisms of action.

   a. *Compare the major chemical classes of hormones.*
   b. *Explain the general mechanisms of hormonal action.*
   c. *Describe the location, hormones, and functions of the following endocrine glands and tissues: pituitary, thyroid, parathyroids, thymus, adrenals, kidneys, heart, pancreas, testes, ovaries and pineal gland.*
   d. *Discuss the results of abnormal hormone production.*
   e. *Explain how hormones interact to produce coordinated physiological responses.*
   f. *Identify the hormones that are especially important to normal growth, and discuss their roles.*
   g. *Define the general adaptation syndrome and compare homeostatic responses with stress responses.*
   h. *Describe the effects that hormones have on behavior.*

3. To establish the background needed to deal with the hormonal regulation of specific systems (Chapters 19, 21, 22, 23, and 26-29).
4. To reinforce material presented in earlier chapters.

a. *The chemical structure of amino acids, proteins, and lipids (Chapter 2).*
b. *The effects of molecular shape and lipid-solubility on the abilities of compounds to cross cell membranes (Chapter 3).*
c. *The role of receptor proteins in membrane transport, and the stability of the transmembrane potential (Chapters 3, 10, and 12).*
d. *The key role that enzymes play in the regulation of intermediary metabolism, and how enzymes can be activated/deactivated (Chapters 2 and 3).*
e. *The gene activation-transcription-translation sequence for protein synthesis, and that enzymes are replaced constantly to keep up with metabolic turnover (Chapter 3).*

❑ Teaching Strategies

1. Analogies

a. Use the following analogy to describe the differences among a prehormone, prohormone, and an active hormone. For your birthday you get one of those super-duper, motorized, remote controlled, deluxe racing cars. When you open the box, however, it doesn't look like a super-duper, motorized, remote-controlled, deluxe racing car. You notice on the outside packaging, in very small lettering: "Some Assembly Required; Batteries Not Included." (The essence of a prehormone: most of the parts are there, but it has a distinctly different structure than the prohormone). So you begin to assemble the car, trimming the unwanted, framing scraps away from the plastic hub-caps, axles, and steering wheel; gluing pieces to the chassis; and finally adding batteries. (The prohormone stage: it has all the parts, in all the right places, but it still hasn't been "switched on.") Now all that's left is to push the "POWER ON" button for your super-duper, motorized, remote-controlled, deluxe racing car to be activated. You can activate it in the house and guide it outside to the driveway, or you can carry it outside in its inactive form, and turn it on once you get to the driveway. (Activation of the hormone can occur within the endocrine gland, or after it leaves the gland).

b. Underscore that the mission of the hormone is to change the activity of the target cell. If a cell is analogous to a mini-factory (see Chapter 3), then it is the hormone's job to change factory production by telling the boss (DNA) to write up different orders, by retooling parts of the factory, or by laying off some workers, letting others work overtime, and retraining some workers to do new jobs.

c. Compare each hormone fitting into its own very specific receptor to a key fitting into a lock. The hormone can only get into the cell if it can "unlock" the gate at the membrane. If there is no lock for that given key, it can't gain entrance into the cell.

d. Have the students draw and label a microscopic view of the thyroid gland, indicating the cuboidal cells and colloid of the follicle and the simple squamous-lined capillaries surrounding the follicles. Explain that in 3-D, each follicle is like a Jello-filled balloon, and the capillaries are like string wrapped around the balloon.

e. It is difficult for students to perceive how tissues can be glucose-starved despite excess amount of glucose in the blood. The Ice Cream truck may be sitting outside

the room with a load of ice cream, but if we don't open the door and let the delivery man in, we won't see a lick of it!

2. Demonstrations

a. Point out the word "renal" within the word adrenal. The adrenal glands are added to the kidneys; i.e., ADD-RENAL. Emphasize that the structural and functional differences seen between the adrenal medulla and cortex are a result of their different embryological origin. Ask the students to give you an example of another gland that has a compound origin. Use the structure of an orange to illustrate the layers of the adrenal gland. The medulla is analogous to the inner pulp of the orange, and the cortex is analogous to the orange peel. While they differ in the number of total layers, the peel's two layers (the outer orange-colored layer and inner white layer) can be used to illustrate the concept of the three layers of the cortex.

b. A powerful, attention-getting device is to have, sitting on the podium or table next to you, an actual specimen cup, filled with a concoction of apple and orange juices (mixed in just the right proportions to have an uncanny resemblance to urine). Report that today urinalysis is done on computers from samples collected in cups (such as the one sitting next to you), but the name diabetes mellitus, "honeyed, free-flowing urine," came from a time when urinalysis included the tasting of urine. This never fails to gross out the students. As they express their disgust, say, "I don't know. Perhaps it isn't that bad." Then pick up the cup and take a taste. Describe the three P's of diabetes (polyphagia, polyuria, and polydipsia). Stress that the polydipsia is a result of the polyuria and not the reverse.

3. Vocabulary Aids

a. Use the following aid to help the students remember that aldosterone retains sodium:

AL DO ST ER ONE

salt (Na^+) retention

b. To distinguish Addison's from Cushing's: Addison's disease results from hypoglucocorticoid secretion so glucocorticoids must be "ADDed." The subcutaneous lipid deposits resulting from hyperglucocorticoid secretion results in a "CUSHy" appearance.

c. Associate the "A" in glucAgon with the "A" in Alpha. Students will sometimes confuse the words glucagon and glycogen. Warn them ahead of time of this pitfall, and make clear which is the hormone and which is the starch. Suggest that they use the "CO" in glyCOgen to remind them that COrn is a starchy vegetable.

4. Applications

a. For some mothers, just thinking of their baby can stimulate the milk let-down reflex.

5. Common Student Misconceptions/Problems

a. Students are sometimes surprised to discover that FSH and PRL exist in both females and males, since they associate these hormones with the development of the follicle in the ovary and stimulation of milk production in the breast.

b. Often the students are surprised to see the kidneys (as well as the heart in the following section) listed as endocrine organs. Explain that the classification as such is a result of endocrine (i.e., hormone producing) tissue located within the kidneys.

6. Lecture ideas

a. Ask the students to draw the five components of a neural reflex arc. Use arrows to indicate afferent, efferent, and negative feedback pathways. Compare that to a simple endocrine reflex, indicating that the endocrine cells are both "receptor" and "control center," the blood is the "efferent pathway," and the target cell is the "effector organ." Indicate the different complexities that can exist in an endocrine reflex if the endocrine gland is under the influence of a regulatory hormone from another gland or a neural connection. Summarize that an endocrine gland will be stimulated (or inhibited) based upon feedback derived from the blood, from release of another hormone, or from nervous activity.

b. Remind the students of the hypophyseal fossa in the sella turcica of the skull and that the pituitary, which sits in the fossa, is an "extension" of the brain at the level of the third ventricle. Given its anatomical location, it is not surprising to see that it is influenced by regulatory hormones and neural connections from the hypothalamus.

c. Since the hypophyseal portal system will not be the only example of a portal system discussed, it is appropriate to define what is a portal system and describe its structural organization. Explain that in the circulatory system, arteries carry blood from the heart to the capillary beds within organs, and veins carry the blood away from the capillary beds within organs back to the heart. In portal systems, arteries carry blood to a capillary bed, which is drained by veins, but then those veins carry blood to a second capillary bed before returning to the heart. The portal system acts as a detour:

TYPICAL SYSTEM:

ARTERIES ➔ CAPILLARIES ➔ VEINS

PORTAL SYSTEM:

ARTERIES ➔ CAPILLARIES ➔ PORTAL ➔ CAPILLARIES ➔ VEINS
VEINS

d. As each hormone of the anterior pituitary is discussed, have the students compare the releasing pattern of the hormone to the patterns depicted in Figure 18-7. They should select the pattern of activity and control that matches the hormone being discussed, draw out the pattern, and fill in the specific hormone names and target organs.

e. Before explaining the function of ADH, ask the students to describe to you the effect of a diuretic. Most have heard of this term, but if they are puzzled, ask them to explain to you the effect of taking a "water pill." Once it is established that a diuretic makes one pee a lot, point out that "diuresis" means free flowing, and under the influence of a diuretic, the body will get rid of water by letting it pass out in the urine. Now ask them what they can deduce about the effect of an anti-diuretic. Explain the stimuli responsible for ADH release and the effect of blocking its release. It is alcohol's inhibiting effect on ADH release that causes people to say, "I can't drink beer; it goes right through me." (Explain that you will resolve why this is a physical impossibility during the discussion of the digestive and urinary systems).

f. The thyroid is the only gland that produces and stores large amounts of hormone. Using the diagrams that the students produced, point out that the production of thyroid hormones, T3 and T4, occurs as a series of events beginning where the cell membrane of the follicular cell comes in contact with the capillary (basement membrane), passing through the follicular cell, and ending up in the lumen of the follicle. However, since the hormones must be released into the blood to affect their target organs, there must be a mechanism that reabsorbs the hormones back into the follicular cells and subsequently back into the blood. Emphasize the close relationship between structural characteristics of the follicular cell and the thyroglobulin protein and the functional role they play in the process: the basal membrane has special iodide pumps, the colloid membrane has microvilli to increase surface area for secretion and reabsorption, and the proper orientation of the Iodinated tyrosines prior to their union relies upon the structural configuration of the thyroglobulin on which the tyrosines are attached.

Ironically, while the details of the process of synthesis, storage, and liberation of thyroid hormones T3 and T4 are more complex than the level of material normally covered in an introductory A & P course, the description of that process ties in cellular structures and functions that were discussed in Chapter 3 (e.g.. membrane pumps, active transport, protein synthesis in the RER, packaging in the Golgi, exo- and endocytosis, peroxisomal activity). Discussing the process, even in a simplified manner, provides the perfect opportunity to review the cellular organelles in situ, and to illustrate how the organelles work together to achieve the cell's primary function. Since the students are more advanced in their knowledge, as compared to the first week or two of the semester, they can view the process with the benefit of a more sophisticated perspective.

g. Rather than simply memorizing the effects of epinephrine and norepinephrine encourage the students to try to understand the logical connection between the effects and the body's needs during a "Fight or Flight" response.

h. The point of INsulin is to get glucose IN the cell. Point out that glucose would diffuse into cells without the aid of insulin since that is the direction of the concentration gradient. Insulin accelerates the uptake to meet the demands of the cells. Ask the students, "What is the significance of brain, kidney, and digestive tract cells being insulin-independent?"

❑ Answers to End of Chapter Exercises

Level 1: Reviewing Facts and Terms

1. a
2. b
3. d
4. a
5. c
6. d
7. b
8. d
9. c
10. b
11. a

12. (1) activation of adenyl cyclase (2) release or entry of calcium ions (3) activation of phosphodiesterase (4) activation of other intracellular enzymes

13. (1) The hypothalamus secretes regulatory hormones that control endocrine cells in the pituitary gland. (2) The hypothalamus contains autonomic centers that exert direct neural control over the endocrine cells of the adrenal medulla. (3) The hypothalamus releases hormones into the circulation at the posterior pituitary.

14. (1) thyroid stimulating hormones (TSH) (2) adrenocorticotropic hormone (ACTH) (3) follicle-stimulating hormone (FSH) (4) luteinizing hormone (LH) (5) prolactin (PRL) (6) growth hormone (GH) (7) melanocyte-stimulating hormone (MSH)

15. (1) antidiuretic hormone (ADH) (2) oxytocin

16. (1) increase in the rate of energy consumption and utilization in cells (2) acceleration in production of sodium-potassium ATPase. (3) activation of genes coding for the synthesis of enzymes involved in glycolysis and energy production (4) acceleration of ATP production by mitochondria (5) In growing children, thyroid hormones are essential to normal development of the skeletal, muscular and nervous systems.

17. The overall effect of calcitonin is to decrease the concentration of calcium ions in body fluids. Parathyroid hormone causes an increase in the concentration of calcium ions in body fluids.

18. (1) zona glomerulosa- mineralocorticoids (2) zona fasciculata- glucocorticoids (3) zona reticularis- androgens

19. Epinephrine and norepinephrine trigger a mobilization of glycogen reserves in skeletal muscles and accelerate the breakdown of glucose to provide ATP. Stored fats are broken down to fatty acids in adipose tissue. Glycogen molecules are broken down in the liver,

and the resulting glucose molecules are released into the circulation. In the heart, stimulation of beta-1 receptors triggers an increase in the rate and force of cardiac muscle contraction.

20. (1) Calcitriol stimulates calcium and phosphate ion absorption along the digestive tract. (2) Erythropoietin (EPO) stimulates the production of red blood cells by the bone marrow. EPO is also involved in the regulation of blood pressure and blood volume.

21. (1) ANP promotes the loss of sodium ions and water at the kidneys. (2) ANP inhibits the secretion of water-conserving hormones, such as ADH and aldosterone. (3) ANP suppresses thirst. (4) ANP blocks the effects of angiotensin II and norepinephrine on arterioles

22. (1) alpha cells-glucagon (2) beta cells-insulin (3) delta cells-somatostatin (4) F-cells-pancreatic polypeptide

23. (a) (1) alarm phase, in which energy reserves are mobilized and the body prepares itself with "fight-or-flight" responses; (2) resistance phase, in which glucorticoids are released to mobilize lipid and protein reserves, conserve glucose for neural tissues, elevate and stabilize blood glucose concentrations, and conserve salts and water and lose K^+ and H^+; and (3) exhaustion phase, in which homeostatic regulation breaks down (b) epinephrine in the alarm phase and glucocorticoids in the resistance phase

Level 2: Reviewing Concepts

24. In communication by the nervous system, the source and destination are quite specific and the effects are short lived. In endocrine communication, the effects are slow to appear and they often persist for days. A single hormone can alter the metabolic activities of multiple tissues and organs simultaneously.

25. Hormones direct the synthesis of an enzyme (or other protein) not already present in the cytoplasm. Hormones turn an existing enzyme "on" or "off." Hormones increase the rate of synthesis of a particular enzyme or other protein.

26. The two hormones may have opposing, or antagonistic, effects. The two hormones may have additive or synergistic effects. One hormone can have a permissive effect on another, i.e., the first hormone is needed for the second to produce its effect. Hormones may produce different but complementary results in specific tissues and organs.

27. Endocrine reflexes are the functional counterpart of neural reflexes, in which a stimulus triggers production of a hormone. Both neural and endocrine reflexes are controlled by negative feedback mechanisms in most cases.

28. Phosphodiesterase is the enzyme that converts cAMP to AMP, thus inactivating it. If this enzyme were blocked, the effect of the hormone would be prolonged.

Level 3: Critical Thinking/Clinical Application

29. Extreme thirst and frequent urination are characteristics of both diabetes insipidus and diabetes mellitus. To distinguish between the two, glucose levels in the blood and urine could be measured. A high glucose concentration would indicate diabetes mellitus.

30. Julie should exhibit elevated parathyroid hormone in her blood. Her poor diet does not supply enough Ca^{++} for her developing fetus. The fetus removes large amounts of Ca^{++} from the maternal blood, lowering the mother's blood Ca^{++} levels. This would lead to an increase in parathyroid hormone and increased mobilization of stored Ca^{++} from maternal skeletal reserves.

31. Sherry's symptoms suggest hyperthyroidism. Blood tests should be performed to assay the levels of TSH, T_3, and T_4. This would allow the doctor to make a positive diagnosis (hormone levels would be elevated in hyperthyroidism) and also determine if it were primary (a problem with the thyroid gland) or secondary (a problem with hypothalamo-pituitary control of the thyroid gland).

32. All of the steroid hormones are quite similar in structure. When there is an excess of one steroid, some is converted to another form, frequently a form similar to aldosterone. Increased levels of aldosterone lead to sodium and water retention and produce the sometimes bloated appearance of patients receiving steroid therapy.

❑ Media Lab Instructor Notes

Web addresses often change. To avoid dead links, we are listing the keywords in parentheses next the to Web Explorations. Simply go to the Companion Website (http://www.prenhall.com/martini), select the Fifth Edition of Fundamentals of Anatomy and Physiology and search using the key word to locate the current address.

Animations (Website)

- Figure 18-3, 18-4—Animation in play / pause format. Mechanisms of hormone activity; suitable for lecture demonstration or self-study after lecture presentation.
- Figure 18-9—Animation with pop-up labels. Pituitary hormones and their target; suitable for self-study review or lecture enhancement while discussing pituitary function.

Animations (CD-ROM)

- Rotating 3-dimensional image corresponding to Figure 18-15 pancreas.

Web Explorations (Overview)
Web Exploration 1 (**ANTERIOR PITUITARY**)

- *Goal*—review, information organization
- *Description of page*—series of slides created by the University of Manitoba for advanced physiology
- *Expectations of student behavior*—study pages, copy feedback diagrams, return to text, add to pages
- *Instructor's role*—assist in page navigation; describe feedback diagrams; define terms
- *Special notes or further uses of exploration*—use the arrow buttons to navigate; beyond page 11 = reproductive charts

Web Exploration 2 (**PARATHYROID**)

- *Goal*—critical thinking, information organization
- *Description of page*—Endocrine web page links on top and bottom; some within article
- *Expectations of student behavior*—write thoughts, read article, revise written work, expand to textual information
- *Instructor's role*—explain terminology in page, assist in pre-writing exercise, compile information
- *Special notes or further uses of exploration*—great source for thyroid, adrenal, osteoporosis and pancreas information; bookmark for student or instructor study later.

Additional Web Explorations
Should the two explorations found in the text not answer your needs, a third exploration is provided below. Your students do not have direct access to this exploration. You must provide them the address and information in the following paragraph.

Web Exploration 3
Estimated time for completion = 5 minutes

Stress—it is more than just a slight annoyance or bad feeling during finals. Review the discussion of Hormones and Stress found in Chapter 18 and read the information on **STRESS** at this site (http://online.sfsu.edu/~psych200/unit10/104.htm). The linked page will give you more information on stress and the general adaptation syndrome. Read this information and on a separate sheet of paper answer the questions posed in the reviews. Now reflect on your own life experiences. Have you experienced stress in your life? Did your symptoms follow those described on this page? You may wish to share your experiences with your peers using the communications tools on the Companion Website.

<u>Web Exploration 3</u> (**STRESS**)

- *Goal*—review, personalize information
- *Description of page*—Psychology 200 class page from SFSU; prose with 2 reviews at end
- *Expectations of student behavior*—read, answer questions, reflect on personal experiences
- *Instructor's role*—describe GAS, point out differences in perspective between psychology and physiology, assist in self-reflection—executive functions?
- *Special notes or further uses of exploration*—can't answer quiz on-line; links to next module not appropriate.

Objectives	TOPIC OUTLINE **Chapter 18** **The Endocrine System** (page 1 of 4)	Figures	Strategies	A/V RESOURCES: Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
1a	**I. Introduction**							
1b	**II. An Overview of the Endocrine System**	18-1		●	●			
2a	A. Hormone Structure							
	1. Amino Acid Derivatives							
	2. Peptide Hormones		1a					
	3. Lipid Derivatives	18-2		●	●			
	B. Hormone Distribution and Transport							
	C. Hormone Function and Mechanisms of Action							
	1. Hormones and the Cell Membrane	18-3		●	●	●		
1c	2. Hormones and Intercellular Receptors	18-4	6a	●	●	●		
	D. Control of Endocrine Activity							
	1. Endocrine Reflexes	18-5		●	●			
2c	**III. The Pituitary Gland**	7-8, 18-6	6b	●	●			
	A. The Anterior Pituitary	18-6	6c	●	●			

Topic Outline				A/V Resources				
Objectives	**Chapter 18** **The Endocrine System** (page 2 of 4)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	1. The Hypophyseal Portal System	18-7		●	●			●
	2. Hypothalamic Control of the Anterior Pituitary	18-8		●	●			
	3. Hormones of the Anterior Pituitary	18-8	5a, 6d	●	●			
	B. The Posterior Pituitary							
	1. Antidiuretic Hormone		6e					
	2. Oxytocin	18-9	4a	●	●	●		
2c	**IV. The Thyroid Gland**	18-10a		●	●			
	A. Thyroid Follicles and Thyroid Hormones	18-10bc, 11	1d, 6f	●	●			
	1. Functions of Thyroid Hormones							
	B. The C Cells of the Thyroid Gland: Calcitonin	18-10bc		●	●			
2c	**V. The Parathyroid Glands**	18-12		●	●			
	A. Parathyroid Hormone Secretion	18-13		●	●			
2c	**VI. The Adrenal Glands**	18-14ab	2a	●	●			
	A. The Adrenal Cortex	18-14c	3a		●			

Topic Outline				A/V Resources				
Objectives	**Chapter 18** **The Endocrine System** (page 3 of 4)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	1. The Zona Glomerulosa	18-14c			●			
	2. The Zona Fasciculata	18-8a	3b	●	●			
	3. The Zona Reticularis	18-14c			●			
	B. The Adrenal Medullae		6g					
	1. Epinephrine and Norepinephrine							
2c	**VII. The Pineal Gland**							
	VIII. The Endocrine Tissues of Other Systems							
	A. The Intestines							
	B. The Kidneys		5b					
	1. Calcitriol							
	2. Erythropoietin							
	3. Renin							
	C. The Heart							
	D. The Thymus							

Topic Outline				A/V Resources				
Objectives	**Chapter 18** **The Endocrine System** (page 4 of 4)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	E. The Pancreas	18-15,16		●	●	●		●
	1. Insulin		1e, 2b, 6h					
	2. Glucagon			●				
	F. The Gonads							
	IX. Patterns of Hormonal Interaction							
2f	A. Hormones of Growth							
2g	B. Hormones and Stress	18-17		●	●			
	1. The Alarm Phase							
	2. The Resistance Phase							
	3. The Exhaustion Phase	18-17		●	●			
2h	C. Hormones and Behavior							
	D. Aging and Hormone Production							
	X. Integration with Other Systems	18-18			●			

CHAPTER 19

Blood

❑ Introduction

Blood substitutes offer an interesting topic to capture students interest about this chapter. The recent risk of the HIV contamination of the blood supply has given new impetus to the search for artificial blood substitutes. This has been furthered by the Armies interest in such substitutes for battlefield emergencies. A recent article by Winslow in the March/April 1997 issue of *Scientific American Science and Medicine* presents an interesting historical overview of this subject. It concentrates mostly on cell free oxygen carrying systems and points out some of the physiological problems encountered with the use of these substitutes. The perfluorocarbons are very interesting because they carry enough oxygen in solution that they an organism can actually breath this in liquid form! There are dramatic pictures available (not in this article though) showing a mouse submerged in this liquid and breathing it.

❑ Instructional Goals/Learning Objectives

1. To emphasize the vital functions of the blood and the significance of blood analysis in clinical diagnosis.

   a. *Describe the important components and major functions of blood.*
   b. *Identify locations on the body used for blood collection and list the basic physical characteristics of the blood samples drawn from these locations.*
   c. *Discuss the composition and functions of plasma.*
   d. *Describe the origin and production of the formed elements in the blood.*
   e. *List the characteristics and functions of red blood cells.*
   f. *Describe the structure and indicate the functions of hemoglobin.*
   g. *Describe the recycling system for worn-out or damaged erythrocytes.*
   h. *Define erythropoiesis and identify the stages involved in RBC maturation.*
   i. *List examples of important blood tests and cite the normal values for each test.*
   j. *Explain the importance of blood typing on the basis of ABO and Rh incompatibilities.*

2. To introduce the white blood cell components, and to establish a conceptual basis for the detailed material in Chapter 22.

   a. *Categorize the various white blood cells on the basis of their structures and functions.*

3. To understand the process of hemostasis.

   a. *Describe the structure, function, and production of platelets.*
   b. *Explain the series of chain reactions that control blood loss after an injury.*

❑ Teaching Strategies

1. Analogies

a. As you approach the subject of the cardiovascular system, you may find it useful to compare the concept of the system with the structural layout of a city. In the rural areas, there are residences that house the people who live and work in the city, while in the core of the city, there are businesses and industries that are responsible for supplying services and goods to the rural areas. (In this analogy, the rural areas represent the peripheral regions of the body, and the core of the city represents the major organs located in the trunk.) Of course there must be communication or a way of transporting people and products back and forth between the two areas. The transportation is done along major highways that extend from the heart of the city into different areas in the periphery and branch into smaller and smaller roads. Roadways, parallel to outbound roads but going in opposite directions, gradually converge to transport items back into the heart of the city (analogous to the arteries and veins). Vehicles are used to carry people and goods back and forth between the two areas (as do the blood cells and plasma). The type of vehicle is determined by the nature of what is being transported (structure and function relationship).

b. Although the concept of fluid compartments will be discussed in detail in Chapter 27 (Fluid, Electrolyte, and Acid-Base Balance), introducing the idea as an initiation into the discussion of the function of blood will help the students become aware of the dynamic exchange of fluid that occurs between the blood plasma and tissues. Explain that the fluid compartments of the body are like the air compartments of an inflatable air mattress typically seen in swimming pools. Within the system, fluid can move freely from one compartment to another depending upon homeostatic "pressures," just as the air within the mattress moves from one compartment to another as you shift your weight and put pressure on different areas. The overall volume of fluid filling the body (or air filling the mattress) remains the same; it just shifts its position. The only way to change the volume of fluid in the entire system is by adding fluid (drinking) or removing fluid (urinating and sweating), just as you can add or remove air from the mattress by inflating or deflating it.

c. Mature erythrocytes are enucleated and are shaped like a donut with a hole that doesn't go all the way through. Their size is approximately equivalent to the diameter of the smallest capillaries; hence, erythrocytes must pass through the capillaries single-file, like ticket holders pass the ticket taker at a movie theater.

2. Demonstrations

3. Vocabulary Aids

a. The MONocyte is the MONster cell that gobbles up debris and pathogens.

4. Applications

a. The concentration of plasma proteins plays a vital role in developing an osmotic pressure gradient that drives fluid into capillaries from the interstitial space.

b. Unless the levels of WBCs are indicative of leukemia, many conditions of leukocytosis represent a normal and temporary response to an infection.

c. Individuals suffering from malnutrition often have bleeding problems due to the lack of calcium and vitamin K in their diets.

d. Individuals who will be having surgery are instructed to avoid taking aspirin or acetaminophen prior to surgery to reduce the chance of excess blood loss due to reduced coagulation ability.

5. Common Student Misconceptions/Problems

a. Ask the students why the kidney is the logical organ for controlling the release of EPO? This concept is puzzling, since most students do not associate kidney function with the circulatory system. Emphasize that the kidney responds to decreased levels of 0_2, not to decreased levels of RBCs.

b. Blood type reactions are often confusing for students to understand. It does not make sense to them, for example, that someone with blood type AB could receive blood type A without an anti-A reaction. They simply look for an exact match and forget that agglutinins will only react to agglutinogens they can see; i.e., agglutinogens will not react to something that is not there. (You only react to the people who walk into a room; if no one walks into the room, it never occurs to you to say "Hello.") Make sure that they understand the distinction between agglutinin and agglutinogen. AgglutiNogens are ON the RBCs and determine blood type. AgglutinINs are IN the blood plasma and cause the agglutINation reaction.

Evaluate the students' understanding of compatibility by having them first write their blood type on a 3 x 5 card (they should make up a type if they do not know their own). Then have them pair up and "donate" their blood to their partner. On the card, they must indicate if the donated blood is compatible with their own. If not, they must indicate which type(s) they need. The pair of students should return the cards to the original "donors" and compare notes to check their answers.

c. Occasionally, students are confused by the designation of extrinsic and intrinsic pathways. Point out that the terms are in reference to the blood, not to the body. Explain that the intrinsic pathway gets its name as a result of factors that are intrinsic to the blood. That is why blood can be removed from the body and still coagulate. It contains all the factors necessary for the coagulation process. The extrinsic pathway relies upon the contribution of tissue factors, factors extrinsic to the blood. That is why the extrinsic pathway proceeds faster; it has the "help" of the tissues.

d. Some of the factors released during the positive feedback cascade are the very factors that will eventually inhibit the coagulation process. This may sound ironic, but it provides a mechanism of control and a method of putting the process in check.

6. Lecture ideas

a. Recall for the students that blood is a connective tissue: the RBCs and WBCs are suspended in an acellular matrix, the plasma. There are no visible fibers, but there are proteins that can be converted to fibers under certain conditions. Stress that the plasma is far more than a passive "filling-in" supportive matrix as seen in other connective tissues. It is an integral structure that plays an active role in the function of blood.

b. Emphasize that the students must become accustomed to the units used for the clinical expression of chemical concentrations in the blood. Often times only the number value is expressed (e.g., a blood glucose level of 90 rather than 90 mg/dL or 90 mg %), and the understanding of the proper units is assumed. Using Table 19.3 as a reference, indicate that the formed elements of the blood are always expressed as #/μL or mm^3. As with plasma chemical concentrations, oftentimes only the number value is expressed, and the understanding of the proper units is assumed.

c. As you explain the clotting factors and the chain reaction of the proenzymes, indicate that the cascade is a good example of a positive feedback mechanism. Ask the students why it is important that the chain reaction for coagulation be so complicated (to minimize the chance of unwanted coagulation).

❑ Answers to End of Chapter Exercises

Level 1: Reviewing Facts and Terms

1. c
2. c
3. a
4. c
5. d
6. a
7. b
8. d
9. d
10. b

11. (1) Transportation of dissolved gases, nutrients, hormones, and metabolic wastes. (2) Regulation of pH and electrolyte composition of interstitial fluids throughout the body. (3) Restriction of fluid losses through damaged vessels or at other injury sites. (4) Defense against toxins and pathogens. (5) Stabilization of body temperature.

12. Albumins-maintain osmotic pressure of plasma, important in transport of fatty acids. Globulins, transport globulins bind small ions, hormones or compounds that might otherwise be filtered out of the blood at the kidneys or have very low solubility in water. Immunoglobulins attack foreign proteins and pathogens. Fibrinogen functions in blood clotting.

13. (a) anti-B agglutinins (b) anti-A agglutinins (c) neither anti-A nor anti-B agglutinins (d) anti-A and anti-B agglutinins

14. (1) Ameboid movement: extension of a cellular process (2) Emigration: squeezing between adjacent endothelial cells in the capillary wall. (3) Positive chemotaxis: attraction to specific chemical stimuli (4) Phagocytosis: the ability to engulf and destroy pathogens

15. neutrophils, eosinophils, basophils and monocytes

16. (1) T cells-responsible for cellular immunity (2) B cells-responsible for humoral immunity (3) NK cells-responsible for immune surveillance

17. (1) M-CSF-monocytes and macrophages (2) G-CSF-granulocytes (3) GM-CSF-granulocytes and monocytes (4) multi-CSF-granulocytes, monocytes, megakaryocytes

18. (1) transport of chemicals important to the clotting process (2) formation of a temporary patch in the walls of damaged blood vessels (3) active contraction after clot formation has occurred.

19. (1) thrombopoietin (TPO) (2) interleukin-6 (IL-6) (3) multi-CSF

20. (1) the vascular phase (2) the platelet phase (3) the coagulation phase (4) clot retraction (5) fibrinolysis

21. The common pathway begins when thromboplastin from either the extrinsic or intrinsic pathways appears in the plasma.

22. An embolus is a drifting blood clot. A thrombus is a blood clot that sticks to the wall of an intact blood vessel.

Level 2: Reviewing Concepts

23. a
24. d
25. b
26. d

27. RBCs are biconcave discs that lack mitochondria, ribosomes, and nuclei. RBCs contain a large amount of the protein hemoglobin.

28. The white blood cells function in defense against toxins and pathogens. Neutrophils, eosinophils, and monocytes engulf and digest bacteria, protozoa, fungi, viruses, and cellular debris. Lymphocytes specialize to attack and destroy specific foreign cells, proteins, and cancerous cells, directly or through the production of antibodies.

29. The blood functions in body temperature regulation by absorbing and redistributing the heat of the body. Heat is absorbed from active skeletal muscles. Dermal capillaries dilate when body temperature rises, thereby increasing blood flow to the skin and dissipating the excess heat to the air. Dermal capillaries constrict when body temperature falls, thereby decreasing blood flow to the skin and thus conserving heat for more temperature-sensitive organs.

30. Arterial puncture is required for checking the efficiency of gas exchange at the lungs. Samples are usually drawn from the radial artery at the wrist or the brachial artery at the elbow.

31. RhoGam is given to prevent an Rh-negative mother from producing anti-Rh-positive antibodies, which could attack the blood of an Rh-positive fetus. Rhogam can be administered soon after delivery of the first Rh-positive baby. RhoGam contains anti-Rh positive antibodies that remove fetal Rh-positive antigens from the mother's circulation before the mother's immune system recognizes their presence. Thus, the mother's immune system is not induced to produce anti-Rh-positive antibodies.

32. Aspirin inactivates platelet enzymes involved in production of thromboxanes and prostaglandins, and inhibits endothelial cell production of prostacylcin. Thus, aspirin inhibits blood clot formation.

Level 3: Critical Thinking/Clinical Application

33. A prolonged prothrombin time and a normal partial thromboplastin time would indicate a deficiency in the extrinsic system, but not the intrinsic system or common pathway. This would indicate a factor VII deficiency.

34. After donating a pint of blood or after any other loss of blood, you would expect to see a substantial increase in the number of reticulocytes. Since there is not enough time for large numbers of erythrocytes to mature, the bone marrow releases large numbers of reticulocytes (immature cells) in an effort to maintain a constant number of formed elements.

35. Mary is suffering from antibiotic-induced thrombocytopenia. You would expect to observe multiple bruises throughout the skin, prolonged bleeding time, and prolonged clotting time.

36. In many cases of kidney disease, the cells responsible for producing erythropoietin are either damaged or destroyed. The reduction in erythropoietin levels leads to reduced erythropoiesis and fewer red blood cells, resulting in anemia.

37. Intrinsic factor, an essential part of the transport system for the absorption of vitamin B_{12} by the intestinal cells, is produced by specialized stomach cells. When most of the stomach was removed, the intrinsic factor was no longer available to facilitate absorption of vitamin B_{12}, therefore, injection directly into the blood stream would be necessary. If the patient refuses or fails to take the B_{12} shots, he will develop pernicious anemia.

38. Antibiotics may kill normal bacteria that reside in the digestive tract. These bacteria are the primary source of vitamin K in the human body, and vitamin K is necessary for the synthesis of prothrombin and some other clotting factors. Thus, loss of vitamin K associated with loss of the bacteria could result in reduction in clotting ability.

❑ Media Lab Instructor Notes

Web addresses often change. To avoid dead links, we are listing the keywords in parentheses next the to Web Explorations. Simply go to the Companion Website (http://www.prenhall.com/martini), select the Fifth Edition of Fundamentals of Anatomy and Physiology and search using the key word to locate the current address.

Animations (Website)

- Figure 19-5—Animation in play / next format. Red blood cell turnover; suitable for lecture demonstration of RBC life span or self-study after lecture presentation.
- Figure 19-10—Animation with pop-up labels (pathways). Origin and differentiation of blood cells; suitable for lecture demonstration of blood cell production or self-study tool.
- Figure 19-11, 19-12—Animation in play / next format. Vascular and platelet phases of hemostasis continuing into 19-14 coagulation phase of hemostasis; suitable for self-study review or lecture enhancement while discussing clot formation.

Web Explorations (Overview)
Web Exploration 1 (**THALASSEMIA**)

- *Goal* —content clarification, review and expand
- *Description of page*—linked page from Children's Hospital Oakland; short prose with internal and top/bottom links
- *Expectations of student behavior*—read page, take notes, review text, synthesize information
- *Instructor's role*—explain hemoglobin function, shape; assist in conceptualization of information
- *Special notes or further uses of exploration*—alpha and beta thalassemia links describe heredity and genetics; can be used as case study in heredity discussion

Web Exploration 2 (**TRANSFUSION**)

- *Goal*—critical thinking, ethics
- *Description of page*—JAMA article reprinted in religious publication; links to other articles at end
- *Expectations of student behavior*—read, discuss implications, arrive at personal decision
- *Instructor's role*—explain transfusion, provide religious background (not available on site)
- *Special notes or further uses of exploration*—end of article links present pro and con—previous article religious, next article medical; links at top go to Watchtower Religious publication.

Additional Web Explorations
Should the two explorations found in the text not answer your needs, a third exploration is provided below. Your students do not have direct access to this exploration. You must provide them the address and information in the following paragraph.

Web Exploration 3
Estimated time for completion = 5 minutes

Infectious mononucleosis is a common childhood disease. It affects the white blood cells, leaving the patient weak and tired. Although many of us are familiar with the disease, few understand it. What causes this disease? How is it detected? What can be done for the patient? To learn the answers to these questions, visit this site on **MONONUCLEOSIS** (http://kidshealth.org/parent/common/mononucleosis.html). Read the information presented, taking note of the causes, population affected, symptoms, detection methods and treatments for this disease. Present the information in pamphlet format similar to those you find in doctor's offices.

Web Exploration 3 (**MONONUCLEOSIS**)

- *Goal*—expand knowledge, concrete application
- *Description of page*—informational page by Nemours Foundation, links on top and bottom to foundation, pages within site; internal links to other diseases
- *Expectations of student behavior*—read, take notes, organize information in pamphlet form
- *Instructor's role*—clarify terminology and testing procedures, help students stay on task
- *Special notes or further uses of exploration*—Links within text provide lab tests; use back button to return to text; good site for family use

Topic Outline				A/V Resources				
Objectives	**Chapter 19** **Blood** (page 1 of 3)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	I. Introduction		1ab, 6a					
1a	**II. Functions of Blood**							
1a	**III. Composition of Blood**	19-1		●	●			
1c	**IV. Plasma**	19-1b		●	●			
	A. Plasma Proteins		6b					
	1. Albumins, Globulins, Fibrinogen							
	2. Other Plasma Proteins							
	3. Origins of the Plasma Proteins							
1d	**V. Formed Elements**	19-1c		●	●			
	A. Hemopoiesis							
1e	B. Red Blood Cells							
	1. Abundance of RBCs							
	2. Structure of RBCs	19-2	1c	●	●			
	3. Hemoglobin	19-3		●	●			

Topic Outline				A/V Resources				
Objectives	**Chapter 19 Blood** (page 2 of 3)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	4. RBCs Life Span and Circulation	19-5		●	●	●		
1	5. RBC Production	19-6		●	●			
	6. Blood Types	19-7		●				
2a	C. White Blood Cells							
	1. WBC Circulation and Movement							
	2. General Functions							
	3. Neutrophils	19-9a			●			
	4. Eosinophils	19-9b			●			
	5. Basophils	19-9c			●			
	6. Monocytes	19-9d	3a		●			
	7. Lymphocytes	19-9e			●			
	8. The Differential Count and Changes in WBC Profiles							
	9. WBC Production	19-10		●	●	●		
3a	D. Platelets	19-9e			●			

TOPIC OUTLINE				A/V RESOURCES				
Objectives	**Chapter 19** **Blood** (page 3 of 3)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	1. Platelet Functions							
	2. Platelet Production							
3b	**VI. Hemostasis**							
	A. The Vascular Phase	19-11		●	●	●		
	B. The Platelet Phase	19-11		●	●	●		
	C. The Coagulation Phase	19-12		●	●	●		
	1. Clotting Factors	19-12a	6c	●	●			
	2. The Extrinsic Pathway		5c					
	3. The Intrinsic Pathway							
	4. The Common Pathway							
	5. Interactions Among the Pathways							
	6. Feedback Control of Blood Clotting		5d					
	7. Calcium Ions, Vitamin K, and Blood Clotting		4c					
	D. Clot Reaction							
	E. Fibrinolysis							

CHAPTER 20

The Heart

❑ Introduction

Given that atherosclerosis is the leading killer in the U.S., one should not miss an opportunity to discuss its etiology and prevention. The disease is very complex and involves several systems. Most students will be aware of the disease but may not be aware of how deadly it is. They also will know something about cholesterol being involved but not exactly how. An excellent article by Woolf and Davies (*Scientific American Science and Medicine*, September/October 1994) discusses many of the details. Point out that the main cause of death from atherosclerosis is not direct blockage of arteries (this takes time and the symptoms bring you to the doctor early enough for intervention). The main killer is blood clots. These can occur early in the disease before any overt symptoms have occurred. Blood clots can kill quickly by triggering a heart attack or stroke. You can tie together information from the blood chapter with this material very nicely. If you have time you might talk about cholesterol homeostasis so that the students have a better understanding of the different types of lipoproteins.

❑ Instructional Goals/Learning Objectives

1. To return to the levels of organization theme, beginning with individual cardiocytes and building up to the effects of unconscious and conscious mental activities on cardiac performance.

    a. *Describe the location and general features of the heart.*
    b. *Describe the structure and explain the functions of the pericardium.*
    c. *Identify the layers of the heart wall.*
    d. *Trace the flow of blood through the heart, identifying the major blood vessels, chambers, and heart valves.*

2. To emphasize the correlations between the organization of the cardiocytes and the performance of the heart as a pump.

    a. *Describe the components and function of the conducting system of the heart.*
    b. *Explain the events of the cardiac cycle, including systole, diastole, and the heart sounds.*

3. To contrast cardiac muscle and skeletal muscle structure; to show how differences in membrane response to stimulation prevent cardiac tetany.

4. To describe how the alterations in membrane permeability or changes in ionic concentrations affect cardiac performance.

    a. *Describe the events of an action potential and explain the importance of calcium ions to the contractile process.*

b. *Describe the effects of hormones, drugs, temperature, and changes in ion concentrations on the heart and heart rate.*

5. To describe the most common diagnostic procedures used to assess cardiac function.

   a. *Identify the electrical events of a normal electrocardiogram.*

6. To introduce the major factors that determine cardiac output, and indicate the significance of this measurement.

   a. *Define stroke volume and cardiac output and describe how each is regulated.*
   b. *Specify the effect of autonomic activity on heart function.*

❑ Teaching Strategies

1. Analogies

a. Since the job of the heart is to provide the pumping force strong enough to send the blood through the vessels, it is necessary to understand the "pattern of flow" in those vessels before examining the anatomy of the heart. The flow pattern of the circulatory system is directly related to the organization of the chambers in the heart.

Before describing the function of the two circuits, ask the students to explain the following sentence from the text book, "... blood returning to the heart from the systemic circuit must complete the pulmonary circuit before reentering the systemic circuit." As obvious as the fundamental purpose of the two circuits may appear to you, it is not always as conspicuous to the students. The following analogy might be a helpful tool. Years ago, milk used to be delivered in glass quart bottles to the doorsteps of people's houses. Each week, the milkman (a politically incorrect term by today's standards, but literal for the time, hence the birth of many a milkman joke) would drive his route, picking up the empty glass bottles from the previous week and leaving new bottles freshly filled with milk. While the obvious purpose of the milkman's delivery route was to bring the milk to the households in need of it and to get rid of the empty bottles left over after using the milk, he could not repeat the delivery route until he went back to the dairy, where he could exchange the empty bottles for full ones. Blood carrying O_2 to the cells of the body and picking up CO_2 must exchange that CO_2 for more O_2 in the lungs. Since RBCs don't have their own little "blood trucks" to power their route, they must start from and return to the heart to be pushed on their way. (The analogy can be stretched to include a garage/gas station that the milkman must pass through before proceeding to the next circuit.)

b. As you discuss the factors affecting EDV, present the following analogy, "I am putting water in a bathtub, and then I turn off the faucet. How much water is in the tub?" Prompt the students to say it depends upon 1) the amount of time you had the tap on and 2) how hard the water was turned on. Draw the analogy to the EDV being affected by the duration of ventricular diastole and the venous return. "Now suppose I pull the plug in the tub. How long will it take to empty the tub?" That will depend upon 1) how much water was in there to begin with (preload), 2) the force of gravity

on the water (the forcefulness of the ventricular contraction), and 3) how big the drain is (the afterload).

2. Demonstrations

3. Vocabulary Aids

a. When discussing the trabeculae carneae note that trabeculae was a term introduced during the anatomical study of a long bone. Also note that the root element for the word carneae is the same as used in the word carnivorous (flesh eater).

4. Applications

a. The cardiac sound can tell a story about what physical events are occurring in the heart, because they are created as a result of the blood hitting against the closed valves (not from the valves slamming shut). Hence, as we hear the first heart sound, we can associate that sound with the closure of the AV valves, which means that we know ventricular systole has begun, even if we cannot see the heart.

5. Common Student Misconceptions/Problems

a. Students will equate arteries with O_2 carrying blood vessels. Underscore that the vessels are named for the direction of blood flow and not for the levels of O_2 or CO_2 in the blood. Indicate that the arteries and veins of the pulmonary circuit are reverse in their gas composition as compared to the arteries and veins in the systemic circuit. **A**rteries carry blood **A**way from the heart. **V**eins gi**V**e the blood back to the heart.

b. As you explain the concept of an electrocardiogram and define the waves, take great care to emphasize that the ECG represents electrical activity in the heart which must precede the physical activity. There is a strong tendency for students to equate the electrical depolarization with the physical contraction. For example, if you ask them to indicate on an ECG tracing the time that would correspond to peak atrial systole, they will signify the onset or peak of the P wave. Direct their attention to Figure 20-11, and point out that the peak of the contraction occurs 100-150 msec after the depolarization event. Ask them to explain the delay.

c. As you define a cardiac cycle, specify that it represents the time and events from the onset of one cardiac event until that event occurs again. A cardiac cycle expressed in terms of cardiac sounds, for example, would begin with the onset of the first heart sound and continue until the onset of that same sound. The cycle would include the pause after the second sound. Expressed in terms of the ECG, it would begin with the onset of the P wave and continue until the next P wave. The tendency is to ignore the period of electrical inactivity between the T wave and the next P wave. Point out that expression of heart rate as beats/minute is nothing more than cardiac cycles/minute.

6. Lecture ideas

a. Before introducing the overview of the circulatory system, it might be advisable to reexamine some of the information that the students have already learned about the

heart. Briefly inspect the histology of cardiac tissue, restating that it is involuntary, striated muscle. Remind the students of the purpose of the intercalated discs. After a histological review, prompt the students to summarize what they recall about the nervous control of the heart (i.e., SNS and PSNS (vagus nerve) influences, β receptors. etc.), as well as what they remember about muscle contraction. Such a review will help to refresh the students' memories and to tie in the relevancy of some of the material learned earlier in the semester.

b. Point out that clinically, evaluation of cardiac activity begins with two basic measurement-assessments they all have been subjects of at some point in their lives. See if they can volunteer the answer: cardiac auscultation and pulse determination. Some students may have also experienced the recording of an ECG, and the point can be made that an ECG measures a third parameter of cardiac function; i.e., electrical conduction through the cardiac tissues. Explain that one of the goals of this chapter is to learn the anatomy and physiology of the heart and be able to connect that knowledge with the various measurements and with the homeostatic controls of cardiac performance.

c. Have the students draw a box divided up into quadrants. Label the quadrants for each chamber and its function.

RIGHT ATRIUM receives blood from body	LEFT ATRIUM receives blood from lungs
RIGHT VENTRICLE sends blood to lungs	LEFT VENTRICLE sends blood to body

d. Encourage the students to think of the valves as exits belonging to the chamber that precedes them during the blood flow (as opposed to entrances belonging to the chamber that they open into). This concept will make it easier to associate their opening and closing with the systolic and diastolic activity of the chamber to which they belong. For example, the AV valves are the exit doors out of the atria, so naturally, they would have to be open for the blood to leave the atria. Likewise, the semilunar valves are the exits belonging to the ventricles, so they must be open during ventricular systole.

e. Have the students trace a drop of blood through the heart by listing the structures in the proper sequence from the superior and inferior venae cavae to the aorta. Make sure that they include names of valves, designation of arteries and veins, and the pulmonary capillaries where gas exchange occurs. They can also return to the box drawing they created to learn the chambers and complete the schematic representation by adding valves, vessels, and arrows to indicate the direction of blood flow.

f. After discussing the coronary arteries and veins, have the students trace a drop of blood by listing the structures in the proper sequence from the aorta (into the left or right coronary artery) back to the right atrium. Make sure that they designate artery or vein and indicate the capillaries in the myocardium where gas and nutrient exchange takes place.

g. Ask the students to draw a schematic representation of the reflex from the stimulus detected by the baroreceptors (or chemoreceptors), along the afferent pathway to the appropriate control center in the medulla, and the efferent pathway (SNS or PSNS) back to the heart. This exercise helps them visualize the anatomical pathway as they learn the physiological control.

h. Stress that the rate and strength of cardiac contraction can be influenced by external nervous and/or hormonal controls, but they are not required to initiate the contraction. Evidence of the heart's intrinsic conduction system is confirmed by the fact that the heart will continue to beat even if it is removed from the body. After discussing the structures of the conduction system, have the students trace the pattern of conduction by listing the structures in the proper sequence from the SA node to the myocardium of the ventricles.

i. Point out that the ventricles never completely empty; there is always an ESV. Obviously, the amount of blood that left the ventricle (SV) is equivalent to the amount of blood that filled the ventricle (EDV) minus the amount of blood that was left in the ventricle after ejection (ESV). Write the equation on the board:

$$SV = EDV - ESV$$

j. Cardiac output (like the blood flow measurement through any organ) is a dynamic measurement, because it is concerned with the amount of blood pumped over a period of time (one minute). Based upon the example given in the text for calculating CO, the heart can eject the body's entire volume of blood in one minute. Write the CO equation on the board:

$$CO = SV \times HR$$

Ask the students questions to verify the relationships of the factors in the equation: "If SV increases and HR stays the same, what will happen to CO?" "If HR decreases, what will happen to CO?" Make sure they understand there is a direct relationship. Indicate that you are first going to discuss all the factors that can make SV increase or decrease, and then you will discuss the factors that make HR increase or decrease.

k. Rewrite the CO equation on the board, and include the factors that influence SV stated earlier:

$$\begin{array}{c} CO = SV \times HR \\ \Uparrow \\ EDV - ESV \end{array}$$

Again, ask the students questions to verify the relationships of the factors in the SV equation. "If EDV increases, what will happen to SV?" "If ESV increases, what will happen to SV?" "If ESV decreases, what will happen to SV?" Make sure that they understand that there is a direct relationship between SV and EDV, but an indirect relationship between SV and ESV. Indicate that you are first going to discuss all the factors that can make EDV increase or decrease, and then you will discuss the factors that make ESV increase or decrease. Essentially, you will be explaining factors that affect SV, since it is a function of EDV and ESV.

Answers to End of Chapter Exercises

Level 1: Reviewing Facts and Terms

1. c
2. b
3. b
4. b
5. a
6. a
7. b
8. a
9. c

10. During ventricular contraction, tension in the papillary muscles and chordae tendinae braces the AV valve cusps and keeps them from swinging into the atrium. This action prevents the backflow or regurgitation of blood into the atrium as the ventricle contracts.

11. (1) The epicardium is the visceral pericardium, which covers the outer surface of the heart. (2) The myocardium is the muscular wall of the heart, which forms both atria and ventricles. It contains cardiac muscle tissue and associated connective tissues, blood vessels and nerves. (3) The inner surfaces of the heart, including the valves, are covered by a squamous epithelium which is called the endocardium.

12. The atrioventricular (AV) valves prevent backflow of blood from the ventricles into the atria. The right AV valve is the tricuspid valve and the left AV valve is the bicuspid (mitral) valve. The pulmonary and aortic semilunar valves prevent backflow of blood from the pulmonary trunk and aorta into the right and left ventricles.

13. SA node - AV node - AV bundle (bundle of His) - R and L bundle branches - Purkinje fibers (into the mass of ventricular muscle tissue).

14. The cardiac cycle is the period between the end of one heartbeat and the beginning of the next heartbeat. The cycle begins with atrial systole as the atria contract and push the blood into the relaxed ventricles. As the atria relax and atrial diastole begins, the ventricles contract (ventricular systole), forcing blood through the semilunar valves into the pulmonary trunk and aorta. The ventricles then relax (ventricular diastole), and passive filling occurs.

15. (1) preload-the stretch on the heart before it contracts (2) contractility-the forcefulness of contraction of individual ventricular muscle fibers (3) afterload-the pressure that must be exceeded before ejection of blood from the ventricles can begin

Level 2: Reviewing Concepts

16. a
17. c
18. d

19. a

20. The right atrium receives blood from the systemic circuit, and passes it to the right ventricle. The right ventricle discharges blood into the pulmonary circuit. The left atrium collects blood from the pulmonary circulation. Contraction of the left ventricle ejects blood into the systemic circuit.

21. Listening to the heart sounds (auscultation) is a simple effective method of cardiac diagnosis. The first and second heart sounds accompany the action of the heart valves. The first sound ("lubb") marks the start of ventricular contraction, and the sound is produced as the AV valves close and the semilunar valves open. The second sound ("dupp") occurs at the beginning of ventricular filling when the semilunar valves close. The third heart sound is associated with blood flow into the atria, and the fourth with atrial contraction.

22. The cardiac output (CO) is the amount of blood pumped by each ventricle in one minute. The stroke volume (SV) is the volume of blood ejected by either ventricle in one systole. CO (ml/min) = SV (ml) x HR (beats/min)

23. Cardiac output is proportional to stroke volume and heart rate (CO = SV x HR).

24. Preload is the degree of stretching of the cardiac cells during ventricular diastole. In cardiac muscle tissue, there are no antagonistic muscle groups to extend the cardiac muscle fibers after each contraction. The necessary stretching force is provided by the blood pouring into the heart, aided by the elasticity of the fibrous skeleton.

25. Sympathetic activation causes the release of norepinephrine by postganglionic fibers and the secretion of norepinephrine and epinephrine by the adrenal medulla. These hormones stimulate cardiac muscle fiber metabolism, increase heart rate and increase the force and degree of contraction. Parasympathetic stimulation causes the release of ACh at membrane surfaces where it produces hyperpolarization and inhibition. The result is a decrease in the heart rate and the force of cardiac contractions.

26. Epinephrine, norepinephrine, glucagon, and thyroid hormones all have positive inotropic effects, which means that they increase the strength of contraction of the heart.

Level 3: Critical Thinking/Clinical Application

27. In skeletal muscles, increased accumulation of lactic acid during exercise decreases the efficiency of contraction, and can ultimately prevent contraction due to muscle fatigue. If this situation occurred in the heart, the results could be fatal. In order to avoid this possibility, the heart can metabolize lactic acid, removing it quickly before it can interfere with cardiac function. This capacity of the heart allows the organ to function over a wider range of oxygen levels and still maintain peak efficiency.

28. This patient is suffering from second-degree heart block, a condition in which not every signal from the SA node reaches the ventricular muscle. In this case, for every two action

potentials generated by the SA node, only one is reaching the ventricles. This accounts for the two P waves, but only one QRS complex. This condition frequently results from damage to the internodal pathways of the atria or problems with the AV node.

29. Person 1 has a cardiac output of 4500 ml or 4.5L (CO = HR X SV). Person 2 has a cardiac output of 8550 ml or 8.5 L. According to Starling's law, in a normal heart the cardiac output will be directly proportional to the venous return. Thus, person 2 should have the greater venous return. Ventricular filling decreases with increased heart rate. Since person 1 has the lower heart rate, the ventricular filling time should be longer.

30. Blocking the calcium channels in myocardial cells will lead to a decrease in the force of cardiac contraction. Since the force of cardiac contraction is directly proportional to stroke volume, you would expect a lower stroke volume in patients taking verapamil.

31. As the result of a myocardial infarction, cardiac muscle cells die. As the cells die, their plasma membranes break down and their cytoplasmic contents leak into the surrounding interstitial fluid. Since the cells contain relatively high concentrations of K^+, the concentration of K^+ in the surrounding fluid increases as K^+ leaks from the dead and dying cells. Since the interstitial fluid now contains more K^+, less K^+ diffuses through the membranes of the living cells, decreasing the potential difference across the membrane and making them more excitable.

32. The extra contraction that is generated by the ectopic pacemaker is accompanied by an extra refractory period. The timing is usually such that the next normal action potential from the AV node arrives while the ventricles are still in the refractory period that accompanies the action potential generated by the ectopic pacemaker. As a result, the action potential does not trigger a contraction and the ventricles are not stimulated again until the next normal signal along the conducting pathways. This longer-than-normal period between subsequent contractions produces the feeling of the heart "skipping" a beat.

❑ Media Lab Instructor Notes

Web addresses often change. To avoid dead links, we are listing the keywords in parentheses next the to Web Explorations. Simply go to the Companion Website (http://www.prenhall.com/martini), select the Fifth Edition of Fundamentals of Anatomy and Physiology and search using the key word to locate the current address.

Animations (Website)

- Figure 20-4—Animation in play / next format. Sectional anatomy of heart; suitable for lecture demonstration of heart structure or self-study.
- Figure 20-13—Animation in play / next format. Impulse conduction through heart; suitable for lecture demonstration of cardiac systolic flow or self-study tool after presentation.
- Figure 20-16—Animation in play / next format. Pressure and volume relationships in the cardiac cycle; suitable for self-study review or lecture enhancement while discussing cardiac cycle.

Animations (CD-ROM)

- Rotating 3-dimensional image of heart corresponding to Figure 20-4 sectional anatomy.

Web Explorations (Overview)
Web Exploration 1 (**ECG**)

- *Goal*—analytical skills, content application
- *Description of page*—ECG library created by Dr Jenkins (Wales) and Dr Gerred (New Zealand); links to strips with anomalies—WELL EXPLAINED!
- *Expectations of student behavior*—study normal page, click to view abnormal strips, return each time to normal
- *Instructor's role*—define ECG and peaks on strip; assist in navigation; assist in copying tracings
- *Special notes or further uses of exploration*—requires some initial study to understand set-up of page; not sequential, students can (will) jump all over; clicking on homepage not productive (difficult to return)

Web Exploration 2 (**MURMUR**)

- *Goal*—observational skills, information synthesis
- *Description of page*—Florida Thoracic and Cardiovascular Assoc site w/ directional links on left
- *Expectations of student behavior*—read, listen, write descriptions using text and page
- *Instructor's role*—discuss murmur, heart sounds, valves; assist in running real audio player
- *Special notes or further uses of exploration*—sounds require RealAudio download; Excellent resource for other heart pathologies—video of surgeries interesting (not well focused).

Additional Web Explorations
Should the two explorations found in the text not answer your needs, a third exploration is provided below. Your students do not have direct access to this exploration. You must provide them the address and information in the following paragraph.

Web Exploration 3
Estimated time for completion = 10 minutes

Heart attack is the number one killer in the United States. One of the newer techniques for diagnosing heart attack looks at serum levels of troponin T. What is troponin T, and why are elevated levels in the blood correlated with acute coronary syndromes? To answer these questions, visit the site on **TROPONIN** (http://www.pslgroup.com/dg/daea.htm). Read the article and answer the following questions: What is troponin T? Why is it a better indicator of acute heart syndrome than ECG or troponin I? How does this study impact your quality of life / health care?

Web Exploration 3 (**TROPONIN**)

- *Goal*—concrete application, link previous information to current topic (muscle contraction)
- *Description of page*—Doctor's guide medical news page, links to DG on top, right and bottom
- *Expectations of student behavior*—read, take notes, refer to text for troponin discussion
- *Instructor's role*—clarify terminology, review sliding filament theory and cardiac muscle cell
- *Special notes or further uses of exploration*—lots of side links to follow—watch student focus; search engine at end will search entire Doctor's Guide references; overwhelming for basic students

TOPIC OUTLINE				A/V RESOURCES				
Objectives	**Chapter 20** **The Heart** (page 1 of 4)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	I. Introduction		6ab					
	II. An Overview of the Cardiovascular System	20-1	1a, 5a	●	●			
1a	**III. Anatomy of the Heart**	20-2ab		●	●		●	
1b	A. The Pericardium	20-2c		●	●			
	B. Superficial Anatomy of the Heart	20-3		●	●	●		●
1c	C. The Heart Wall	20-4,5		●	●			
	1. Cardiac Muscle Tissue	20-5bcd		●	●			
	D. Internal Anatomy and Organization	20-6ac	6c	●	●			●
	1. The Right Atrium	20-6ac		●	●			
	2. The Right Ventricle	20-6ab	3a		●			
	3. The Left Atrium	20-6ac		●				
	4. The Left Ventricle	20-6ac		●				
	5. Structural Differences between the Left and Right Ventricles	20-7		●	●			

Objectives	TOPIC OUTLINE **Chapter 20** **The Heart** (page 2 of 4)	Figures	Strategies	A/V RESOURCES Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
1d	6. The Heart Valves	20-8	6de	●	●			●
	E. Connective Tissues and the Fibrous Skeleton	20-8		●	●			●
	F. The Blood Supply to the Heart	20-9	6f	●	●			●
	1. The Coronary Arteries	20-9		●	●			●
	2. The Cardiac Veins	20-9		●	●			●
	IV. The Heartbeat							
	A. Contractile Cells							
4a	1. The Action Potential in Cardiac Muscle Cells	20-11a		●	●			
4b	2. Calcium Ions and Cardiac Contractions	20-11b		●	●			
2a	B. The Conducting System	20-12	6h	●	●		●	●
	1. The Sinoatrial (SA) Node	20-13 [step 2]		●	●	●		●
	2. The Atrioventricular (AV) Node	20-12a,13 [step 2]		●	●			
	3. The AV Bundle, Bundle Branches, and Purkinje Fibers							

Topic Outline				A/V Resources				
Objectives	**Chapter 20 The Heart** (page 3 of 4)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
5a	C. The Electrocardiogram	20-13,14	5b	●	●			
2b	D. The Cardiac Cycle		5c				●	
	1. Phases of the Cardiac Cycle	20-15		●	●			
	2. Pressure and Volume Changes in the Cardiac Cycle	20-16	6i	●	●	●		
	3. Heart Sounds	20-17	4a	●	●			●
	4. Energy for Cardiac Contractions							
	V. **Cardiodynamics**	20-18	6j	●	●			
	A. Overview: The Control of Cardiac Output	20-18,19		●	●			
6a	B. Factors Affecting The Stroke Volume		6k					
	1. The EDV		1b					
	2. The ESV							
	C. Factors Affecting the Heart Rate							
6b	1. Autonomic Innervation	20-20,21		●	●			

TOPIC OUTLINE | **A/V RESOURCES**

Objectives	**Chapter 20** **The Heart** (page 4 of 4)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	2. Hormones							
	D. Exercise and Cardiac Output	20-22		●	●			
	VI. The Heart and the Cardiovascular System							

CHAPTER 21

Blood Vessels and Circulation

❑ Introduction

We are often so caught up in teaching students about the newest and most exciting discoveries in physiology that we don't think of history as providing interesting material. The historical development of our concepts of circulation of the blood make a fascinating story and illustrate many important aspects of the scientific approach to problems. Try introducing this chapter's material by discussing the ideas about blood circulation prior to the work of William Harvey. The idea that blood is produced by the liver, sent through the veins and consumed in the tissues offers an opportunity to pose a problem that students can then try to solve via the knowledge they gain in this chapter. Ask them how they know this isn't true. This can be expanded to include the early idea that the arteries are the main source of propulsion of the blood, the heart acts to cool the blood, the lungs refresh the blood by pumping air into the heart where it mixes with blood giving up "vital spirit" to the blood. Discuss why this isn't all so absurd given what was known at the time. Using quotes from Harvey is a fun way to discuss the evidence for our current views. Harvey's calculation of how much blood leaves the heart in one day showed that there was more blood flowing than could possibly be made in the liver in one day. Many of his other arguments are simple, logical and convincing. Point out that Harvey's logic was so convincing that the idea of capillaries was accepted on theoretical grounds long before Malpighi found them with a microscope.

❑ Instructional Goals/Learning Objectives

1. To familiarize students with the basic circulatory patterns in the body; to link the distribution and nomenclature of vessels to familiar anatomical features, especially the peripheral nerves.

    a. *Describe how and where fluid and dissolved materials enter and leave the circulatory system.*
    b. *Distinguish between the types of blood vessels on the basis of their structure and function.*
    c. *Identify the major arteries and veins and the areas they serve.*
    d. *Identify the principal blood vessels and the functional characteristics of the special circulation to the brain, heart, and lungs.*

2. To emphasize the significance of blood pressure as it relates to peripheral blood flow.

    a. *Describe factors that influence blood pressure and how blood pressure is regulated.*
    b. *Explain mechanisms that regulate blood flow through arteries, capillaries, and veins.*
    c. *Discuss the mechanisms and various pressures involved in the movement of fluids between capillaries and interstitial spaces.*

d. *Explain how the activities of the cardiac, vasomotor, and respiratory centers are coordinated to control blood flow through the tissues.*
e. *Describe how central and local control mechanisms interact to regulate blood flow and pressure in the tissues.*

3. To acknowledge the complexity of factors influencing blood pressure, and to demonstrate how those factors can be analyzed individually or in combination.

   a. *Explain how the circulatory system responds to the demands of exercise, hemorrhaging, and shock.*
   b. *Discuss the effects of aging on the cardiovascular system.*

4. To overcome any remaining student fears of equations and calculations.

5. To return to the levels of organization theme; to consider components of the cardiovascular system and integrate that system with others.

❑ Teaching Strategies

1. Analogies

a. Recall for the students the analogy of viewing the blood vessels as a system of highways and smaller branching roads that carry blood to and from different parts of the body (it is not uncommon for the roads of a city to be referred to as arteries). From major thoroughfares, there are many exits that allow one to drive in any one of a variety of different directions. The exit chosen will determine (and be determined by) the desired destination. Once an exit has been made off the main highway (conducting arteries), medium-sized roads (distribution arteries) travel through townships. Smaller roads (arterioles) branch from the medium-sized roads to connect to neighborhoods. Finally, it is the narrow streets, avenues, and lanes (capillaries) that bring one to his/her final destination. At first, these small boulevards, where traffic moves rather slowly, seem inconsequential compared with the larger, fast-moving expressways; but further analysis demonstrates that it is the small streets that are the most important part of the entire system. They are the functional roads (i.e., they are the roads that allow you to arrive at the door of your destination).

   This analogy helps to familiarize the students to the visual concept of arteries and veins, but it is important to emphasize that the blood vessels are far more than passive conduits of blood. While comparing blood vessels to roadways that start as major highways and continue to branch into progressively narrowing streets provides an excellent visual image of the vascular plan, the analogy falls short of accurately portraying blood vessels as dynamic structures that, under homeostatic controls, are constantly changing physical parameters to influence the rate of blood flow.

b. Compare the elastic fibers in the tunica media to an Ace™ bandage wrapped around the vessel; it provides flexible support as the force of blood flow within the vessel ebbs and flows.

c. As you describe the effect of venoconstriction on the volume of blood within the arterial and capillary systems, relate the image to that of squeezing different segments of one of those long, skinny balloons that carnival clowns twist into different shapes. If you squeeze the nose of the poodle, the air fills the ears, giving them more volume.

d. Compare the decrease in pulse pressure as it gets further from the source of that pressure to the ripples made after a rock is tossed into a pool of water. The big, initial splash occurs at ventricular ejection. Waves of pressure are emitted, rippling outward in circles. As the waves get further from the point of origin, the ripple becomes smaller and smaller.

e. While most students are familiar with the process of blood pressure reading, they do not usually connect the sounds with the physical events. Compare the squeezing of the pressure cuff against the artery to someone pushing against the outside of a swinging door after class preventing the students in the room from getting out. As long as the person on the outside exerts a force on the door greater than the opposing force of the students in the room, no one will be able to swing the door open to escape the room. If the person on the outside decreases his pressure slightly (as occurs when the air is deflated from the cuff) then eventually someone on the inside will be able to oppose the outside force and escape from the room. The pressure the student exerted on the door at the time of his/her escape exceeded the pressure of the person on the outside (systolic pressure). As the person on the outside of the door continues to ease-up with the pressure he is using against the door, more and more students in the room will be able to push their way out. If the outside person stops pushing altogether and opens the door (release of the cuff), then the movement of students from inside the room to the outside flows smoothly without exerting any extra force (diastolic pressure).

f. Since only molecules small enough to fit through the pores or fenestrations of the capillary can be filtered out of the blood, the capillary wall acts like a sieve or colander. The spaghetti stays in; the water strains out.

g. You can go back to the analogy of roadways when discussing cardiovascular regulation. If your driveway or the street in front of your house needs repair, you must either fix it yourself, or ask the local city government to do the repair. Either way, the repair is being done at the capillary or arteriole level. Central governments, state or federal, must be responsible for maintenance of the larger roadways.

2. Demonstrations

a. Describe resistance (as a "**squeezing** in" force on the blood exerted by the wall of the blood vessel.) Unless they have had some background in physics, students have trouble distinguishing resistance from hydrostatic pressure. Describe resistance and hydrostatic pressures in terms of squeezing in or pushing out. There are always two pressures involved in a blood vessel: the pressure of the wall of the vessel squeezing in on the blood inside (resistance) and the pressure of the blood inside pushing out against the wall of the vessel (hydrostatic).
It is conveniently visual to use the analogy of a garden hose when describing vascular

resistance and hydrostatic pressure. Providing the following scenario not only helps to describe hydrostatic pressure and resistance, but it also serves to illustrate how an increase in hydrostatic pressure is directly proportional to blood flow, while an increase in resistance is inversely proportional to blood flow (F=P/R). "Imagine that you are outside, watering your front lawn with a garden hose, and the hose is not quite long enough to reach to the corner of the yard. How can you make the water from the hose squirt the extra distance? One way would be to go back to the house and open up the faucet, so that more water is running through the hose. This would create an increase in hydrostatic pressure as the volume of water on the inside of the hose increased and "pushed" more forcefully on the walls of the hose. The extra push or pressure would cause the water to squirt out farther at the end, and because there is more volume of water, there would be an increase in water flow as well (i.e., an increase in the amount of water coming out over a minute). Hence, increasing the volume inside the hose, will increase hydrostatic pressure and water flow. Suppose the faucet was in the back of the house, and you didn't feel like walking to it; then what could you do? You could use your finger to close off part of the opening at the end of the hose. This action has the same effect of decreasing the diameter of the hose (making the opening smaller) which is equivalent to increasing the resistance, or the "squeezing in" of the walls of the hose on the water inside. The result is to make the water squirt out the end with an increased force (even though the stream of water is thinner). You must be careful with this method, because if you cover the end of the hose completely, the increase in resistance is so high that water flow stops. So increasing resistance might help to increase the water pressure, but it decreases the water flow". Which requires more "sucking" power: to draw soda up a straw or to draw a thick milk shake up a straw?

b. It might help to demonstrate to the students the chemical relationship between increased carbon dioxide and decrease in pH (i.e., why the former causes the latter). Alert them to the connection so that when the theme is brought up again during the discussion of the respiratory controls and buffering, the association will at least be familiar.

3. Vocabulary Aids

a. Enunciate "arteriosclerosis" and "atherosclerosis" carefully so that the students can hear the differences in the words as well as see the differences in their spelling. Point out that "sclero" means hard and that arteriosclerosis is the general condition, while atherosclerosis is a specific type of arteriosclerosis.

b. The names for the venae cavae describe their size ("cavernous veins").

c. Veins are sometimes referred to as compliance vessels, since they are easily stretched with an increase in blood volume. They comply, or yield, to an increased volume of blood flowing through them.

d. The different names for the aorta designate the parts of one vessel as it travels from the heart down the body, not the location of several vessels. The aorta is such a long vessel, that it is necessary to describe its parts as ascending, arch, descending

thoracic, and descending abdominal. Most arteries that feed the thoracic, abdominal, pelvic, and iliac regions arise, directly or indirectly, from the aorta.

e. The word "celiac" comes from the same word element as "coelom," which means "cavity." The celiac is the first branch off the aorta in the abdominal cavity.

f. The "mesentery" is the fold of the visceral peritoneum that holds the intestines in place.

g. The Greek word element "pero-" means "deformity," and the word "peroneal" refers to the fibula, considered to be somewhat of a deformity as compared to the tibia. Thus, the peroneal artery runs along the fibula. Warn the students against confusing the peroneal artery with the perineal area, yet another argument supporting the need to spell correctly!

h. The arrangement of the brachial, basilar, and cephalic veins is like a tripod. The brachial makes up the posterior leg of the tripod (it lies posterior to the humerus), and the basilar and cephalic make up the side legs (located on either side of the humerus). If the arm is extended laterally, the "basilar" vein is at the base" of the arm, and the "cephalic" vein is on the superior surface, near the head ("cephalic").

i. In a portal system, arteries carry blood to a capillary bed (in this case, the digestive organs), which is drained by veins, then those veins carry the blood to a second capillary bed (in the liver) before returning to the heart via the inferior vena cava.

j. The umbilical arteries and vein are named based upon the location of the fetal heart, not the maternal heart.

4. Applications

a. The students probably have heard LDLs referred to as "bad cholesterol" and HDLs referred to as "good cholesterol."

b. Cardiovascular disease is the leading cause of death in postmenopausal women; hence the benefits of estrogen replacement therapy (ERT) may outweigh the risks related to breast cancer, depending upon the woman's personal and family medical history.

c. The great saphenous is a common source for grafts during cardiac bypass surgery.

5. Common Student Misconceptions/Problems

a. Although you may define an artery as a vessel that carries blood away from the heart, students have trouble letting go of the misconception that arteries carry oxygenated blood and veins carry deoxygenated blood. Point out that while this is true in the systemic circulation, it is not so in the pulmonary circulation or fetal circulation. Emphasize that an artery is defined by the direction of blood flow and NOT by the amount of oxygen within the blood.

b. Most students have difficulty visualizing what is meant by a capillary "bed," and the massiveness of the capillary beds that are located throughout the body. They will look at a picture such as Figure 21.6, which is meant to be a representation, and they will envision a few capillaries in the tips of their fingers, ends of their toes, and at the top of their head. Try to impress upon them that the bulk of our body has far more capillaries than it has arteries, arterioles, venules, or veins, and that when there is reference to a capillary bed, it is a massive network, as elaborate and branched as a spider's web. Try to develop the image of what our bodies would look like if everything except the capillaries was somehow removed or digested away. Individual features would cease to exist, but the body and organ form would be maintained, and we would appear as if we were made of a network of threads or spider webbing.

c. Many students panic when they are confronted with mathematical equations, because they do not see them as relationships expressed in variables. Talk them through the mathematical relationships as you describe the graphs in Figure 21.9. Ask them to explain the following. If increased resistance increases pressure, how come the pressure is so low in the capillaries, which are considerably smaller in diameter than an artery?

d. Since the ventricles are in diastole for a longer period of time than they are in systole, the average pressure their force creates in the arteries (MAP) cannot be calculated by simply taking the mid-point of the pulse pressure (PP). Thus, if someone's blood pressure is 120/80 mmHg, their PP = 40, but their MAP is NOT the average of 120 and 80 (i.e., 100). Instead, MAP = 93, a pressure lower than PP, due to the longer diastolic phase.

e. Learning the location of blood vessels can seem like a Herculean task for students. You should impress upon them NOT to try to just memorize the names of vessels. Now is when they should rely on the analogy of roadways. Make the following observation. "If I asked you to give me directions from the school to your house, you would not only be able to tell me the names of the roads to travel, but you would be able to include landmarks and crossroads. When you relate the directions, you rely on a mental image that you have created for yourself as you travel from school to home. You are able to conjure up that mental map as the need arises. Learning the blood vessels should be no different. At this point, you have not had the experience of "traveling" along the blood vessels, so you do not have a mental image of their patterns; there is no mental map in your memory to which you can refer. As you study the flow of blood through arteries from the heart and veins back to the heart, think of the patterns as roads of a city map. Imagine yourself walking or driving along those roads, and try to visualize landmarks and crossroads you may pass along your way to a particular destination. In addition to using the analogy as a learning aid, suggest the following as tools that might facilitate the process:

- Much can be determined by just examining the name of the blood vessels, since they are usually named for their location or the organs that they feed or drain. Hence, if there is reference to an axillary artery, then one can imagine it as an artery carrying blood into the arm passing through the axially region.

- Since our bodies are bilaterally symmetrical, most vessels are paired, left and right, and usually the anatomical placement of a vessel on one side is a mirror image of the vessel on the other. In addition, arteries traveling to an organ are usually paired with and have the same name as the veins coming from that organ. Example: L/R renal arteries and L/R renal veins.

- If a vessel's name includes an adjective describing an anatomical direction or a plane of reference, there is probably an analogous vessel with the opposite adjective. Hence, if there is an *external* iliac artery, there will be an *internal* iliac artery. If you locate a *superior* vena cava, than expect that there will be an *inferior* vena cava. The term *common* generally refers to the junction of two vessels. The *common* iliac vein is a "communion" of the internal and external iliac veins.

- Practice the vessel pathways by selecting an arbitrary origin and destination. Trace the blood from the origin to the destination by listing the names of the vessels in the correct order. Make sure to designate left or right and artery or vein. Remember, the only way to get from an artery to a vein is through a capillary bed; the only way to get from a vein to an artery is through the heart and pulmonary circuit.

f. Because generally, veins lie adjacent to arteries, and because it is easier to begin identifying larger veins and then examine the branches that feed into those larger veins, the study of the systemic veins is often approached in the same manner as identifying the systemic arteries. Typically, the student starts at the heart and proceeds to the appendages. For this reason, students sometimes forget that veins carry blood TOWARD the heart, and when they go from the superior vena cava to the brachiocephalic veins, for example, they are moving up stream. Remind them not to fall into the trap. For example, if they are examining the renal vein, they should remember that the blood in that vein flows FROM the kidney TO the inferior vena cava.

6. Lecture ideas

a. As you describe each tunica of the blood vessel wall, relate its structure to the contribution it will make to the function of the whole vessel. For example, ask the students, "What is the function of smooth muscle?" "What do you suppose its effect will be on the blood vessel?" "Why is there more smooth muscle in an artery than in a vein?" "What role will elastic tissue play?" "Why is a capillary made up of only the endothelium of the tunica intima?" "Why do large blood vessels need their own blood vessels (vasa vasorum)?"

b. Since capillaries are the only blood vessels whose walls permit exchange of gases, nutrients, and wastes across their thin, endothelial membrane, they could be considered the "functional unit" of the blood vessel system; that is, it is in the capillaries where the work gets done. Stress that they are the most important component of the vessel system.

c. Review Table 21 - 1. Point out:

- **Hydrostatic pressure** exerts its force from inside the blood vessel against the walls of the blood vessel.

- Since liquid flows down a pressure gradient (just as molecules flow down a concentration gradient), circulatory pressure is an important driving force to keep the blood flowing from the time it leaves the left ventricle until it returns to the right atrium.

- When someone refers to their blood pressure, they are talking about the hydrostatic pressure of the blood in the arteries, before it gets to the capillaries. Venous pressure is the hydrostatic pressure in the veins, after the blood leaves the capillaries.

- The "applied force" used in the definition of hydrostatic pressure is the resistance, and important factors during homeostatic control of blood pressure are vasoconstriction and **vasodilation.**

d. Before detailing the processes of diffusion, filtration, and reabsorption as they relate to capillary exchange, define the nomenclature in terms of net direction of movement. Filtration generally refers to movement of a substance from *inside* the capillary (i.e., in the blood) to *outside* the capillary (i.e., out to the interstitial fluid). A filtration pressure would be the pressure that would be required to push the substance from the blood across the membrane to the interstitial space. Since you have defined hydrostatic pressure as a pressure that pushes out against the wall of the vessel, it stands to reason that hydrostatic pressure will be the driving force behind filtration at the arteriole end of the capillary. (This is not to say that hydrostatic pressure cannot occur in the opposite direction, but in order to simplify the introduction to the concept, define in terms of net osmotic pressure). Reabsorption generally refers to movement of a substance from *outside* the capillary (i.e., *out* from the interstitial fluid) to *inside* the capillary (i.e., *in* the blood). In Chapter 3, osmotic pressure was described as a pressure that "sucks" things across a membrane. Osmotic pressure will be the driving force that "sucks" substances *into* the blood at the venule end of the capillary (i.e., net osmotic pressure). Diffusion relies upon a concentration gradient. Since both filtration and osmotic pressures are occurring at the same time, it is the net result of each that must be examined to understand what the final effect will be on the movement into or out of the blood. At the arteriole end of the capillary, net hydrostatic pressure pushing fluid out of the blood is greater than net osmotic pressure drawing fluid back in. Hence, filtration occurs. In contrast, at the venule end of the capillary, net osmotic pressure drawing fluid in is greater than net hydrostatic pressure pushing out. The result is reabsorption. Provide for the students different scenarios (hemorrhaging, dehydration, injection of a hypertonic solution into the blood, etc.) and have them predict what the effect will be on net filtration or osmotic pressures and blood or tissue volume.

e. Remind the students of the role of plasma proteins in developing an osmotic pressure gradient that drives fluid into capillaries from the interstitial space as discussed in Chapter 19.

f. As you describe the function of the baroreceptors known as pressoreceptors of the carotid and aortic sinuses, the concept mapping of Figure 21-16 will help demonstrate the chain of events as blood pressure rises above or falls below normal. To aid in the visualization of the process, you should draw, as the students copy, the anatomical layout. Illustrate the location of the receptors, the afferent nerves to the cardiovascular centers of the medulla, the efferent nerves, and the target organs (vessels and heart). Ask the students to explain what would happen to blood pressure and cardiac output if someone stands on his/her head.

g. Emphasize that since the window of tolerance for blood pH (7.35-7.45) is so small, it is imperative to have sensory neurons that monitor hydrogen ion concentrations.

h. Ask the students to hypothesize as to the adaptation advantage to having special controls for the brain, heart, and lungs. Such a question requires that they must think about all of the homeostatic mechanisms and the impact that these three organs have on the rest of the body.

i. When the nervous and endocrine systems were discussed, the complementary parallels of the two systems were mentioned. The nervous system is quick to respond, and its effects are short-lived. In contrast, the endocrine system is slower to respond, and its effects are longer lasting. Hence, while the nervous system can provide second-to-second control over cardiovascular regulation, the endocrine system can provide both short-term and long-term effects. Remind the students that they are already familiar with the effect that epinephrine and norepinephrine from the adrenal medulla have on cardiac output, and the hormones that impact cardiac output and vasoconstriction were introduced in Chapter 18.

j. Before explaining the mechanism of EPO release, ask the students to rationalize why increasing the number of RBCs might be an appropriate response to a decrease in blood pressure.

k. Contrast the effects of Angiotensin II with those of Atrial Natriuretic Peptide.

l. Have the students rationalize why patients with hypertension are instructed to restrict salt from their diet or are advised against using decongestants that contain ephedrine.

m. The highway exits off the aortic arch are arteries that eventually bring blood to the arms, neck and head. Demonstrate that the arrangement is not symmetrical. There is a brachiocephalic artery (exit 2A off Interstate Aorta) that gives rise to the right subclavian and right common carotid arteries (hence, the name brachiocephalic = arm, head). But if one wanted to travel to the left arm or the left side of the head, one would have to take Exits 2B and 2C, respectively. There is no left brachiocephalic; the left subclavian and left common carotid branch directly from the aorta. If comparative anatomy dissection accompanies the study of the vessels in an animal

such as the fetal pig or cat, it will be necessary to point out that these animals have only two branches off the aortic arch; the left common carotid branches from the brachiocephalic artery. Unlike the arteries branching from the aorta, the veins that flow into the superior vena cava are symmetrical.

n. The subclavian artery is continuous with the ***axillary*** artery, which is continuous with the brachial artery, which then branches into the radial and ulnar arteries. One can determine the demarcation between the vessels by examining the anatomical structures of the immediate area. For example, the subclavian becomes the axillary as soon as it passes from the thoracic cavity beyond the rib cage. The axillary becomes the brachial as it enters the arm. The brachial ends at the antecubital area.

o. Make these points as you describe the carotid arteries and the blood supply to the brain:

- The branching of the common carotid into the internal and external carotids is sometimes referred to as the bifurcation ("two branches") of the carotid.

- The carotid sinus is the location of the baro and chemoreceptors discussed during cardiovascular regulation.

- The vagus nerve lies adjacent to the common carotid. Taking the carotid pulse is sometimes popular among people who are engaged in aerobic exercise and who want to determine their "working heart rate." Palpation of the carotid can inadvertently stimulate the vagus nerve, which will have the effect of *decreasing* the heart rate, at a time when the demands of the body require an *increased flow rate.* As a result, the person can faint. For this reason, it is recommended that the radial pulse be used to determine working heart rate.

- Remember that the internal carotid feeds the brain; the external carotid feeds the face. The brain is more ***internal;*** the face is more ***external.***

- Use Figure 21-26 to point out that the vertebral arteries travel up through the transverse foramina of the cervical vertebrae. (The presence of the foramina was a way of distinguishing the cervical from the thoracic and lumbar vertebrae in Chapter 7.)

- The internal carotid arteries flow directly into the Circle of Willis; the vertebral arteries get there via the basilar artery.

p. Ask the students to comment on the fact that the celiac artery, the superior mesenteric artery, and the inferior mesenteric artery are unpaired (i.e., why?).

q. As seen with the arteries of the arm, the external iliac artery forms a continuous line feeding into the femoral, popliteal, and posterior tibial. The boundaries of each artery are determined by anatomical landmarks. For example, the inguinal ligament is the dividing line between the external iliac and the femoral artery, the popliteal artery is behind the knee, and the posterior tibial continues from there behind the leg. The

anterior tibial branches where the popliteal becomes the posterior tibial. Another way of looking at it is that the popliteal artery gives rise to the anterior and posterior tibial arteries in the same manner as the brachial artery gives rise to the radial and ulnar arteries.

r. As an introduction into the discussion of the hepatic portal system, ask the students to observe and comment on the fact that there are no abdominal veins draining the digestive organs and flowing directly into the inferior vena cava; that is, there does not seem to be a celiac vein, a superior mesenteric vein, nor an inferior mesenteric vein entering the vena cava. The "logic" of the hepatic portal system can be explained with the following analogy. Pretend that you go to the grocery store and buy a bunch of food. After bringing the groceries home, you don't sit down and eat everything all at once, do you? (Not unless all you bought was donuts.) You sort out the groceries, and put some in the cupboard, some in the refrigerator, some in the freezer (maybe you eat a few chocolate chip cookies). As you sort, you might wash the fresh fruit or lettuce to get rid of any dirt, and you might take the chocolate chip cookies out of the package to store them in the cookie jar. The body goes through the same process. When the food you eat is digested and absorbed into the blood, there is much more in the blood than might be needed at the moment, and the body needs to get rid of any pathogens or toxins that might have been ingested inadvertently. The organ in the body responsible for "sorting out the groceries" is the liver. Hence, all the nutrient rich (but oxygen poor) blood from the digestive organs must travel to the liver before it can be returned to the general circulation. It is the liver's job to repackage, store, and destroy pathogens. It is the function of the hepatic portal system to carry the blood from the digestive organs to the liver.

s. Introduce the topic of fetal circulation by asking, "Why is it counterproductive for all the blood in the fetus to be sent to the lungs for oxygenation?" "What organ performs that function in adults?" "What organ performs that function in a fetus?" Point out that the variations seen in the structure of a fetal heart enable it to function differently than an adult heart. The main point to the structural differences is to get from the right side of the heart to the left side of the heart without having to go through the lungs.

❑ Answers to End of Chapter Exercises

Level 1: Reviewing Facts and Terms

1. k
2. w
3. g
4. o
5. a
6. q
7. c
8. u
9. x
10. b
11. v
12. r
13. e
14. i
15. t
16. f
17. m
18. h
19. d
20. l
21. j
22. p
23. n
24. s
25. d
26. b
27. c
28. a
29. b
30. b
31. a
32. a
33. d
34. b
35. c
36. b
37. d
38. c
39. b
40. c
41. a
42. c
43. b

44. (a) Systolic pressure - the peak blood pressure measured during ventricular systole. (b) diastolic pressure - minimum blood pressure at the end of ventricular diastole. (c) pulse pressure - the difference between the systolic and diastolic pressure. (d) mean arterial pressure - MAP, a single value for blood pressure, is calculated by adding one third of the pulse pressure to the diastolic pressure.

45. (a) Fluid leaves the capillary at the arterial end primarily in response to hydrostatic pressure. (b) Fluid returns to the capillary at the venous end primarily in response to osmotic pressure.

46. (1) muscular compression of peripheral veins (2) the respiratory pump

47. (1) decreased tissue O_2 levels/increased CO_2 levels (2) generation of lactic acid or other acids by tissue cells (3) increased concentrations of K^+ or H^+ in the interstitial fluid (4) chemicals released during local inflammation (5) elevated local temperature

48. (1) a decrease in the cardiac output due to parasympathetic stimulation and inhibition of sympathetic activity (2) widespread peripheral vasodilation due to the inhibition of excitatory neurons in the vasomotor center.

49. The chemoreceptor reflexes respond to changes in the carbon dioxide, oxygen, or pH levels in the blood and cerebrospinal fluid.

50. (1) epinephrine/norepinephrine (2) aldosterone (3) antidiuretic hormone (4) angiotensin II (5) erythropoietin (6) atrial natriuretic peptide

51. Before the exercise begins, there is a slight increase in heart rate due to a general rise in sympathetic activity as you think about the workout ahead.
    - -Extensive vasodilation occurs.
    - -Venous return increases.
    - -There is a rise in cardiac output.

52. hypotension: systolic pressures below 90 mmHg; pale, cool, and moist ("clammy") skin; confusion and disorientation; rapid, weak pulse; cessation of urination; a drop in blood pH (acidosis)

53. When an infant takes its first breath, the lungs expand, and so do the pulmonary vessels. The smooth muscles in the ductus arteriosus contract, isolating the pulmonary and aortic trunks, and blood begins flowing through the pulmonary circuit. As pressure rises in the left atrium, the valvular flap closes the foramen ovale, completing the circulatory remodeling.

54. Age-related changes in:
    - -blood
        - (a) decreased hematocrit
        - (b) formation of thrombin
        - (c) valvular malfunction
    - -heart
        - (a) reduction in maximum cardiac output
        - (b) changes in the activities of the nodal and conducting fibers
        - (c) reduction in the elasticity of the fibrous skeleton
        - (d) progressive atherosclerosis
        - (e) replacement of damaged cardiac muscle fibers by scar tissue
    - -blood vessels
        - (a) progressive inelasticity in arterial walls
        - (b) deposition of calcium salts on weakened vascular walls
        - (c) formation of thrombi at atherosclerotic plaques

Level 2: Reviewing Concepts

55. d
56. c
57. b
58. c

59. Artery walls are generally thicker. They contain more smooth muscle and elastic fibers, enabling them to resist and adjust to the pressure generated by the heart. Venous walls are thinner and the pressure in the veins is less than that in the arteries. Arteries constrict more than veins when not expanded by blood pressure, due to a greater degree of elastic tissue. The endothelial lining of an artery has a pleated appearance because it forms folds, being unable to contract. The lining of a vein looks like a typical endothelial layer.

60. Precapillary sphincters at entrances to capillaries cause alternating contractions and relaxations resulting in a series of pulses, producing variations in blood flow, a process called vasomotion.

61. Continuous capillaries have small gaps between adjacent endothelial cells that permit the diffusion of water and small solutes into the surrounding interstitial fluid, but prevent the loss of blood cells and plasma proteins. Fenestrated capillaries contain pores due to an incomplete or perforated endothelial lining, permitting very rapid exchange of fluids and solutes between the interstitial fluid and the plasma. The walls of arteries and veins are several cell layers thick, and are not specialized for diffusion.

62. Movement in the surrounding skeletal muscles squeezes venous blood toward the heart; this is known as the muscular pump. The muscular pump is assisted by the presence of valves in the veins, which prevent backflow of the blood. The respiratory pump results from the increase in internal pressure of the thoracic cavity upon exhalation, which pushes venous blood into the right atrium.

63. Cardiac output and peripheral blood flow are directly proportional to blood pressure. The blood pressure is closely regulated by a combination of neural and hormonal mechanisms. The resistance of the circulatory system opposes the movement of blood. Blood flow is inversely proportional to the resistance. Sources of peripheral resistance include vascular resistance, viscosity and turbulence.

64. The brain receives arterial blood via four different arteries. Because these arteries form anastomoses inside the cranium, interruption of any one vessel will not compromise the circulatory supply to the brain.

65. The cardioacceleratory and vasomotor centers are stimulated when a general sympathetic activation occurs. The result is an increase in cardiac output and blood pressure. When the parasympathetic division is activated, the cardioinhibitory center is stimulated, reducing cardiac output.

66. The top number (150) is the systolic pressure, the peak blood pressure measured during ventricular systole. The bottom number (90) is the diastolic pressure the minimum blood pressure at the end of ventricular diastole. The MAP (mean arterial pressure) is a single value for blood pressure, and is calculated by adding one-third of the pulse pressure to the diastolic pressure. Mrs. B's MAP is 110, (150-90)/3 + 90 = 110. (Note: pulse pressure = systolic pressure - diastolic pressure.)

    Since Mrs. B is borderline with high blood pressure, she should monitor her blood pressure closely as she could easily become hypertensive. She should consult her physician, but behavioral therapies such as exercising regularly, quitting smoking and restricting intake of salt, fats and calories may be sufficient to lower her blood pressure.

67. The accident victim is suffering from shock and acute circulatory crisis characterized by hypotension and inadequate peripheral blood flow. The hypotension results from loss of blood volume and decreased cardiac output. Her skin is pale and cool due to peripheral vasoconstriction; the moisture results from sympathetic activation of sweat glands.

Falling blood pressure to the brain causes confusion and disorientation. If you took her pulse, you would find it to be rapid and weak, reflecting the heart's response to reduced blood flow and volume.

68. In congestive heart failure, the heart is unable to produce enough force to circulate the blood properly. As more and more fluid accumulates in the capillaries, the blood hydrostatic pressure increases and the blood osmotic pressure decreases. This results in a fluid shift from the blood to the interstitial space. The fluid accumulation exceeds the ability of the lymphatic system to drain it, resulting in peripheral edema (swelling in the extremities).

Level 3: Critical Thinking/Clinical Application

69. There are three contributing factors to Bob's elevated blood pressure. (1) The loss of water through sweating increases blood viscosity. The number of red blood cells remains about the same, but because there is less plasma volume, the concentration of red cells is increased, thus increasing the blood viscosity. Increased viscosity increases peripheral resistance and contributes to increased blood pressure. (2) The heat. In order to cool Bob's body there is increased blood flow to the skin. This in turn increases venous return, which increases stroke volume and cardiac output (Starling's law of the heart). The increased cardiac output can also contribute to increased blood pressure. (3) The heat stress that Bob is experiencing leads to increased sympathetic stimulation (the reason for the sweating). Increased sympathetic stimulation of the heart will increase heart rate and stroke volume, thus increasing cardiac output and blood pressure.

70. The greater saphenous vein of the leg is a large vein that lies just beneath the skin, with no muscle to support it as with the deeper leg veins. Also, being in the legs, the vessel is more susceptible to the effects of gravity than vessels in the arms. When there is any impediment to blood flow from the legs, there is a tendency for blood to collect in the greater saphenous and stretch it (the skin does very little to resist the stretching). Even if the valves in the vein are closed, their edges won't meet due to the stretching and more blood will collect inferior to the valves causing even more stretching. This positive feedback mechanism leads to the black-and-blue nodules known as varicosities in the vein.

71. Pulse pressure is the difference between the systolic and diastolic pressures. The heart rate of a resting athlete is slower than that of a nonathlete, due to the size and condition of the heart muscle. The athlete will have the same or even slightly higher cardiac output as a nonathlete, however. This occurs because the athlete's stroke volume is greater. The larger the stroke volume, the greater the difference between the systolic and diastolic pressures (the systolic pressure is proportional to the volume of blood ejected per beat). Thus, since the athlete has the larger stroke volume, he or she should have the larger pulse pressure.

72. Since antihistamines and decongestants are sympathomimetic drugs, they will have the same effects on the body as stimulating the sympathetic nervous system. In addition to the desired effects of counteracting the symptoms of the allergy, these medications can produce an increased heart rate, increased stroke volume, and increased peripheral resistance, all of which will contribute to elevating blood pressure. If a person suffers from hypertension (high blood pressure), these drugs will aggravate this condition, with potentially hazardous consequences.

73. When Jolene rapidly moved from a lying position to a standing position, gravity caused her blood volume to move to the lower parts of her body away from the heart, decreasing venous return. The decreased venous return resulted in a decreased EDV, leading to a decreased stroke volume and cardiac output. This resulted in decreased blood flow to the brain, where the diminished oxygen supply caused her to be light-headed and feel faint. This usually does not occur because as soon as the pressure drops due to blood moving inferiorly, the baroreceptor reflex should be triggered. Normally, a rapid change in blood pressure is sensed by baroreceptors in the aortic arch and carotid sinus. Action potentials from these areas are carried to the medulla oblongata, where appropriate responses are integrated. In this case, we would expect an increase in peripheral resistance to compensate for the decreased blood pressure. If this doesn't compensate enough for the drop, then an increase in heart rate and force of contraction would occur. In normal individuals these responses occur so quickly that they do not notice any changes in pressure following changes in body position.

❑ Media Lab Instructor Notes

Web addresses often change. To avoid dead links, we are listing the keywords in parentheses next the to Web Explorations. Simply go to the Companion Website (http://www.prenhall.com/martini), select the Fifth Edition of Fundamentals of Anatomy and Physiology and search using the key word to locate the current address.

Animations (Website)

- Figure 21-12—Animation in play / pause format. Capillary filtration; suitable for lecture demonstration of blood hydrostatic pressure or self-study.
- Figure 21-13—Animation in play / next format. Forces acting across capillary walls; suitable for lecture demonstration of fluid movement across capillaries or self-study tool after presentation.
- Figure 21-19—Animation in play / next format. Shock; suitable for self-study review or lecture enhancement while discussing feedback loops and shock.
-

Animations (CD-ROM)

- Rotating 3-dimensional image of arteries corresponding to Figure 21-22, Overview of the Systemic Arterial System.
- Rotating 3-dimensional image of veins corresponding to Figure 21-29, Overview of the Systemic Venous System.

Web Explorations (Overview)
Web Exploration 1 (**NEW VESSELS**)

- *Goal*—critical thinking, content application
- *Description of page*—Doctor's Guide to Medical / other information; lots of links and distractions
- *Expectations of student behavior*—read central article, take notes, synthesize information and discuss applications
- *Instructor's role*—explain role of FGF-1 and genetic research; define terms; help students organize
- *Special notes or further uses of exploration*—requires guidance as there are many links (useless for the most part)

Web Exploration 2 (**VARIANTS**)

- *Goal*—observational skills, critical thinking
- *Description of page*—Virtual Hospital encyclopedic link to all major vessels; page bottom links to rest of site
- *Expectations of student behavior*—click, compare to text, analyze information
- *Instructor's role*—point out vessel pathways, assist with tracing vessels, guide student thoughts
- *Special notes or further uses of exploration*—lots of encyclopedic information on this site, but difficult to utilize effectively.

Additional Web Explorations
Should the two explorations found in the text not answer your needs, a third exploration is provided below. Your students do not have direct access to this exploration. You must provide them the address and information in the following paragraph.

Web Exploration 3
Estimated time for completion = 5 minutes

We have all heard of varicose veins. A short description of this problem is included in your text. What causes varicose veins, and how are they treated? To investigate this question, visit this site **VARICOSE** (http://uhs.bsd.uchicago.edu/uhs/infoline/veins.htm). Read the short description presented. Try to draw your interpretation of what causes a varicose vein. Diagram the surgery that is discussed in the article for presentation in poster format. It may be helpful to work in groups to interpret the procedure.

Web Exploration 3 (**VARICOSE**)

- *Goal*—concept visualization, vein anatomy review
- *Description of page*—University of Chicago Primary Care page, text only
- *Expectations of student behavior*—read, take notes, refer to text for visualization help, draw
- *Instructor's role*—explain varicose veins; assist in understanding surgical procedure; provide visualization aids (models, other posters)
- *Special notes or further uses of exploration*—No links to other information; self-contained module

Topic Outline				A/V Resources				
Objectives	**Chapter 21** **Blood Vessels and Circulation** (page 1 of 5)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	I. Introduction		1a, 4a					
1a	**II. The Anatomy of Blood Vessels**							
1a	A. The Structure of Vessel Walls	21-1	6a	●	●			●
	B. Differences Between Arteries and Veins	21-1		●	●			
	C. Arteries	21-2	4a, 5a	●	●			
	1. Elastic Arteries	21-2	1b	●	●			
	2. Muscular Arteries	21-1,2		●	●			
	3. Arterioles	21-2	3a	●	●			
	D. Capillaries		6b		●			
	1. Continuous Capillaries	21-3a		●	●			
	2. Fenestrated Capillaries	21-3b		●	●			
	3. Capillary Beds	21-5	5b	●	●			●
	4. Vasomotion							
	E. Veins	21-1,2		●	●			●

Topic Outline				A/V Resources				
Objectives	**Chapter 21** **Blood Vessels and Circulation** (page 2 of 5)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	1. Venules							
	2. Medium-Sized Veins							
	3. Large Veins		3b					
	4. Venous Valves	21-6		●	●			
	F. The Distribution of Blood	21-7	1c, 3c	●	●			
	III. Cardiovascular Physiology	21-8	2a	●	●			
2a	A. Pressure							
	B. Resistance							
	1. Vascular Resistance							
	2. Viscosity							
	3. Turbulence							
	C. An Overview of Circulatory Pressures	21-9,10	5c, 6c	●	●			
2d	D. Arterial Blood Pressure	21-10	5d	●	●			
	1. Elastic Rebound							

TOPIC OUTLINE

Objectives	Chapter 21 Blood Vessels and Circulation (page 3 of 5)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	2. Pressures in Small Arteries and Arterioles	21-10	1de	●	●			
2b	E. Capillary Exchange		6d					
	1. Diffusion							
	2. Filtration	21-12	1f	●	●	●		
	3. Reabsorption	3-7	6e	●	●			
2c	4. The Interplay between Filtration and Reabsorption	21-13		●	●	●		
2d	F. Venous Pressure and Venous Return	21-9		●	●			
	1. Muscular Compression	21-6		●	●			
	2. The Respiratory Pump							
	IV. Cardiovascular Regulation	21-14	1g	●	●			
2e	A. Autoregulation of Blood Flow within Tissues	21-5		●	●			
	B. Neural Mechanisms							
	1. Vasomotor Tone							

A/V RESOURCES: Transparency, Still-CD, Anim-CD, Video Tutor, Quiz Art

Topic Outline				A/V Resources				
Objectives	**Chapter 21** **Blood Vessels and Circulation** (page 4 of 5)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	2. Reflex Control of Cardiovascular Function	20-8b,21-15, 16, 24	2b, 6fg	●	●			
	3. CNS Activities and the Cardiovascular Centers							
2d	D. Hormones and Cardiovascular Regulation	21-17	6i	●	●			
	1. Antidiuretic	21-17a		●	●			
	2. Angiotensin II	21-17a		●	●			
	3. Erythropoietin	21-17a	6j	●	●			
	4. Atrial Natriuretic Peptide	21-17b	6kl	●	●			
3a	**V. Patterns of Cardiovascular Response**							
	A. Exercise and the Cardiovascular System							
	1. Light Exercise							
	2. Heavy Exercise							
	3. Exercise, Cardiovascular Fitness, and Health							
	4. Exercise and Cardiovascular Disease							

Objectives	TOPIC OUTLINE **Chapter 21** **Blood Vessels and Circulation** (page 5 of 5)	Figures	Strategies	A/V RESOURCES Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	B. Cardiovascular Response to Hemorrhaging	21-18		●	●			
	1. Short-Term Elevation of Blood Pressure	21-17a		●	●			
	2. Long-Term Restoration of Blood Volume							
	VI. The Blood Vessels	21-20	5e	●	●			
	A. The Pulmonary Circuit	21-21		●	●			
	B. The Systemic Circuit							
	1. Systemic Arteries	21- [22-28]	3d-g, 6m-q	●	●	●		●
	2. Systemic Veins	21- [29-34]	3hi, 4c, 5f, 6r	●	●	●		●
	C. Fetal Circulation		3j, 6s					
	1. Placental Blood Supply	21-35		●	●			
	2. Circulation in the Heart and Great Vessels							
	3. Circulatory Changes at Birth	20-6ac		●	●			
3b	**VII. Aging and the Cardiovascular System**							
	VIII. Integration with Other Systems	21-37			●			

CHAPTER 22

The Lymphatic System and Immunity

Introduction

Students find autoimmune diseases very interesting. They are often surprised to find out how many diseases they've heard of are of autoimmune etiology. These diseases can be used as examples throughout the rest of the course to demonstrate pathology of various systems. The article by Eisenbarth and Bellgrau in the May/June 1994 issue of *Scientific American Science and Medicine* is a good source of information on these diseases. Also, the entire September 1993 issue of *Scientific American* is devoted to the immune system. This is an excellent source of information and ideas. It also contains an article on autoimmune disease (Steinman).

Instructional Goals/Learning Objectives

1. To provide an integrated view of specific and nonspecific defenses.

   a. *Identify the major components of the lymphatic system and explain their functions.*
   b. *Discuss the importance of lymphocytes and describe where they are found in the body.*
   c. *Describe the structure and functions of the lymphoid tissues and the lymphoid organs.*
   d. *List the body's nonspecific defenses and describe the components and mechanisms of each.*
   e. *Define specific resistance and identify the forms and properties of immunity.*
   f. *Distinguish between cell-mediated immunity and humoral immunity and identify the cells responsible for each.*

2. To emphasize the cellular interactions and the complexity of the immune response and to show how clinical problems are related to known mechanisms of immunity.

   a. *Discuss the different types of T cells and the role played by each in the immune response.*
   b. *Describe the general structure of an antibody molecule and the different types of antibodies.*
   c. *Explain the effects of antibodies and how they are produced.*
   d. *Discuss the primary and secondary responses to antigen exposure.*
   e. *List the hormones of the immune system and explain their significance.*
   f. *Describe the origin, development, activation, and regulation of resistance.*
   g. *Explain the origin of autoimmune disorders, immunodeficiency diseases, and allergies; describe their clinical symptoms, and list important examples of each.*

❑ Teaching Strategies

1. Analogies

a. Describe the endothelial cells of the walls of the lymphatics as flaps that overlap like the scales of a fish or the shingles of a roof. The overlying end of the cell is attached to the tissue surrounding the outside of the vessel, but its underlying end is unbound and projects into the lumen. The underlying end acts as a one-way swinging door, allowing substances outside the vessel to enter, but not to exit. Use your hands or a drawing on the board to illustrate this process indicating that once something has entered, it is trapped inside the vessel. Compare it with the action of the small door on a VCR: you can push the door open and insert the video tape, but you can't pull the door out. Not only does the overlapping arrangement prevent lymph from escaping once inside the vessel, it acts like the valves within veins and forces the lymph to flow in one direction.

b. As you describe the different immune cells and their function, compare them to the different units in the organization of military troops. For example, in the Immune Corps there are two divisions: nonspecific immunity and specific immunity (since both divisions are fighting the same war, there is often shared action between the divisions). Each division is made up of regiments. The lymphocytes are a regiment of the specific immune division. The T and B cell battalions within each regiment are divided into platoons, such as helper T cells, cytotoxic T cells, and suppressor T cells (NK cells are a special unit).

c. Stress the fact that cytotoxic T cells must make physical contact with the pathogen. That is, they engage in cell-to-cell combat (like two soldiers having in hand-to-hand combat). It is for this reason that cytotoxic T cells are associated with cell-mediated immunity. Unlike T cells, B cells can send out a non-cellular protein to react with an antigen (like a soldier shooting a gun and the bullet destroying the target). Hence the name, antibody-mediated immunity.

d. Students tend to think of the lymphocytes as static (i.e., they stay in one location). Remind them that they are constantly on the move. The troops (cells) of each platoon must be on constant surveillance, and so they are constantly changing their position as they guard the body against invaders. They can travel the highways or pass through the center of the forts (lymph nodes) located throughout the body.

e. The platoons of T cells must reside at Fort Thymus until they complete basic training. Once they have finished their special training and obtain their orders (differentiation), they can leave the fort prepared to foray against unsuspecting invaders.

f. The spleen acts like a large recycling plant, getting rid of RBCs that are abnormal or "past their prime" and recycling the iron contained within the cells. Since the blood circulates through it, the spleen is in a strategic position to act as a border patrol and to alert the T and B cell troops should an infiltrator try to penetrate through the circulatory system.

g. Phagocytes are special battalions of the WBC regiment in the Nonspecific Division. These battalions are made up of platoons of microphages and macrophages. They act as the scouts and are strategically located in areas that are likely to be compromised by the enemy. Microphages are usually destroyed during a single phagocytic event. The microphages frequently perform Kamikaze or suicide missions-the loss of a few for the benefit of the masses. Macrophages are larger, so they can survive several encounters with the enemy. They even help out by cleaning up the debris left from the small microphage battles. Some are stationed in permanent locations and wait for the invaders to arrive, others are allowed to wander around looking for trouble.

h. The endothelial "markers" and chemotaxic factors are like flares, released to alert the troops.

i. Specific Immunity is the second division of the Immune Corps. Its battalions of B and T cells rely on some of the troops in the first division, but they fight their battles using different weapons, so they need different training. Once they receive their orders (differentiation), they can move around in order to detect infiltrators. When B cells encounter an invader, they can shoot their specific bullets (antibodies) at the invader in order to destroy it. These bullets will continue to hang around, so that if they encounter the exact same invader they can destroy it without having to wait for the B cells to gather and shoot. Cytotoxic T cells must engage in hand-to-hand combat; they must come in contact with the invader. Helper T cells and the macrophages help the cytotoxic T cells (and B cells) by hunting down the invader, handcuffing the culprit to them, and then presenting the enemy to the cytotoxic cell for liquidation. Occasionally, a suppressor T cell will send out orders instructing the cytotoxic cell to be tolerant of certain "questionables," since they do not present a threat. Both B and T cells have the ability to remember their enemy once they have been exposed to it. They use this memory to alert new B and T cells, and they begin to multiply into entire memory squads. These memory squads are on constant patrol for the reoccurrence of an enemy invasion. This provides an advantage over the nonspecifiç immunity division, in that they can seek out and immediately recognize and respond to the invader even more effectively than the first encounter. A first encounter means they have to stop and check the apparent enemy with the master list of enemies to see if this one is on the list. However, they are ready for subsequent encounters, since they have developed a memory of the culprit. In the process of their battles, they often send up flares to call in the troops from the first division, so that they can take advantage of the inflammatory maneuvers.

j. Compare the properties of specific resistance to those of nonspecific immunity. Emphasize the fact that nonspecific immunity is an ecumenical, repeated-from-step one, series of preprogrammed steps that respond to the generic pathogen. Specific immunity is precise and definitive. It targets a specific pathogen and is not "turned on" otherwise. Compare nonspecific and specific immunities to answering a phone. We have been conditioned to answer the phone when it rings. Every time it rings, we answer it the same way. There is never any variation, because we are responding to the ring, not to the caller, and the ring is the same no matter who calls. If we had some way of responding to the caller, our response might be different; i.e., more specific. If we could recognize the caller by the manner in which the phone rings, we

would be able to respond to the caller immediately (as long as it was someone with whom we were familiar). Instead of saying, "Hello," and waiting for the caller to be identified in order to determine what to say next, we would know who was calling, and we might pick up the phone and say, "No, thank you. I'm not interested in aluminum siding." The receptors on the T and B cells are the key to specificity. It is the receptors that allow cells to recognize the antigens as soon as the "phone rings."

k. The snack shop analogy used in the textbook is an effective parallel to the concept of specificity. Another analogy that could illustrate specificity and memory would be the idea behind selling personalized stationry. When you (the antigen) walk into a stationry store, you expect to see a few representative samples of stationry and styles of printing (undifferentiated lymphocytes). You would never expect to be able to walk up to the shelf and pull out a box of stationry with your name and address, because you have never been identified. However, after you are identified, and the clerk has determined what stationry you want (activation), he/she can order as many items as you would like (cloning). Each item would be marked with your personal identification (differentiation). If you return to the store, the clerk will know you immediately (memory) and can respond much more quickly, since he/she knows exactly what to expect from you. If you visit the store with some frequency, the clerk would probably preorder your items and keep them in stock, so that you hardly have to walk in the door before someone responds to you.

l. T helper cells are a "bridge" between the nonspecific and specific immune responses.

2. Demonstrations

a. It might be helpful to compare the constant and variable segments of antibody structure to Lego™ pieces. Imagine five large Lego™ pieces as the constant segments, each with a different shape and color to represent each of the classes of antibodies. At one end, each piece has a recessed surface that enables it to attach to a projection on the surface of a B cell. The shape and color of the piece will determine the job it does. So if you replace a yellow G piece with a red A piece, you would be changing the class of antibody on the B cell surface. Now imagine that you have another set of Lego™ pieces to represent the variable ends. Each variable piece can be attached to a constant piece at one end and an antigen at its other end. The antigen binding site becomes sensitive for a specific antigen after activation (that is why it is called variable, its structure varies depending upon the antigen). Hence, if the variable and constant Legos™ are attached, the result is an antigen specific antibody. In order to get different classes of antibodies with the same specificity, all you have to do is mix and match the Lego™ pieces.

3. Vocabulary Aids

a. The afferent and efferent lymphatics are named in the same way as the afferent and efferent neural pathways were named. If the node is thought of as the "center" (like the control center in the reflex arc), then afferent lymphatics carry to the center and efferent lymphatics carry from the center.

b. The network of sinuses within the lymph node can be compared to an elaborate maze. Associate the "T" in cortex to remember that the T cells are in the cortex of the node.

c. Perforin gets its name, because it "perforates" the membrane of the target cell.

d. In the apoptosis process, the T cytotoxic cell uses a "pop" gun and "pops" the cell out of existence.

4. Applications

a. Many adults in their 40s and 50s do not have their palatine tonsils, because it was routine to remove the tonsils of children a generation or two ago.

b. Explain the reasoning behind taking an antihistamine. Ask the students what symptoms they experience before taking the medication and what relief they get after they take the medication.

c. CD4 T cells are the cells that are destroyed by HIV.

5. Common Student Misconceptions/Problems

a. Most students are surprised to find out that there is a second network of vessels throughout the body that does not carry blood and is not powered by the pumping of the heart. They may be aware of the existence of lymph nodes (especially if they have experienced swollen glands), but they are not clear as to the function of those nodes, nor do they have a sense that the nodes are connected to anything.

b. Visualizing a one-way network of vessels that is NOT a circuit (i.e., the vessels carry the lymph from the periphery to the veins and not back again) is a new paradigm for the students. Explain that since the filtering of the lymph only occurs in the periphery, all that is needed is a system of vessels to transport the lymph back to its source (the blood).

c. Students know from experience that there is a lot of pain when an injury is inflamed, so they have a hard time believing that the inflammatory response is a GOOD thing. Stress that it is the culmination and orchestration of all the other cells and chemicals that have been discussed thus far. In this one nonspecific event, the pathogen or harmful substance is isolated, destroyed, and healing of the damaged tissue begins. It is such an important defense mechanism that it will overlap with the specific immune response. The inflammation process pictured in Figure 22-13 will help the students organize their thoughts. In addition, encourage them to make a list of the events and to draw the cells and chemicals involved. In other words, they should develop their own pictorial concept map. This will enable them to include most of the factors of nonspecific immunity, and will give them an excellent opportunity to organize their thoughts and alert them to questions they might have. Summarize by noting the four signs of an inflammatory response: redness, local warmth (distinguish this from fever), swelling, pain. Discuss events that bring about each of those signs.

d. The students may be puzzled by the idea of self antigens, since they equate antigens with something bad. Point out that an antigen is simply a flag or marker on a cell's surface. If the T cell has "learned" to recognize markers that mean "Me" (MHC), then it knows to ignore the cell. Ask the students to explain why tolerance is an important property of immunity. Try expressing tolerance on a continuum, with complete tolerance at one end, and no tolerance at the other. What would happen if there was too much tolerance (immunodeficiency disease) or not enough (autoimmune diseases)? The appropriate balance becomes apparent. MHC proteins are like the cell's fingerprints. All the cells of your body have the same, unique fingerprints, which makes your cells different from anyone else's cells.

6. Lecture ideas

a. Since the lymph and lymph vessels were referenced in the previous chapter's analysis of capillary dynamics, that is an effective place to begin the discussion of the lymphatic system. Introduce the topic by reminding the students of the two driving forces that affect net filtration pressure in a capillary: hydrostatic pressure and osmotic pressure. Net hydrostatic pressure at the arteriole end of the capillary pushes fluid out of the vessel into the interstitial space, and net osmotic pressure at the venule end of the capillary draws fluid back into the capillary. As stated in Chapter 21, of the 24 liters of fluid moved out of the capillary in a period of a day, about 20-21 liters are reabsorbed. Now pose the following two questions: 1) What do we mean by "fluid"? and 2) What happens to the other 3-4 liters of fluid? Alter some discussion, explain that another term for the "fluid" that is being moved out of and back into the blood vessel is lymph, and it is derived from the plasma that is filtered through the capillary wall during the filtration process. Discussion of the second question might be approached by asking the students to think about what would happen after a month, if the lymph simply stayed in the interstitial space (they often have not thought to equate swelling with edema or do not realize that for it to be called edema, the fluid must be in the interstitial space).

b. The importance of the complement system and complement cascade should be stressed. As elaborate as its events may appear to the students, the complement system has two main goals: 1) to stimulate the inflammatory response and 2) to cause cell lysis and bacterial destruction. Complement activation involves a positive feedback loop that results in a cascade of events. Ask the students if they recall where else positive feedback leading to a domino effect occurred (blood clotting).

c. As you discuss the types of acquired immunity, first define the terms active, passive, natural, and artificial. Point out that active/passive are used to describe whose immune system was involved in the production of the antibodies; natural/artificial are used to describe the method in which the antigen or antibody entered the body. Organize the material on the board in a grid-like presentation and give an example of each:

	ACTIVE	PASSIVE
NATURAL	ACTIVE NATURAL Ex: exposure to chicken pox	PASSIVE NATURAL Ex: maternal antibodies crossing the placenta
ARTIFICIAL	ACTIVE ARTIFICIAL Ex: immunization against polio	PASSIVE ARTIFICIAL Ex: vaccination against the effects of a snake bite

d. Stress that an allergic response is classified as immediate or delayed hypersensitivity based upon the lymphocyte of first contact, not just upon the time from exposure to onset of symptoms, though they are related. B cell lymphocyte activation triggers an immediate hypersensitive response; T cell activation triggers a delayed response.

❑ Answers to End of Chapter Exercises

Level 1: Reviewing Facts and Terms

1. b
2. c
3. b
4. a
5. c
6. a
7. c
8. d
9. d
10. c

11. (1) Thoracic duct: collects lymph from the body below the diaphragm and from the left side of the body above the diaphragm. (2) Right thoracic duct: collects lymph from the right side of the body above the diaphragm.

12. (a) cytotoxic T cells: lymphocytes responsible for cell-mediated immunity (b) helper T cells: stimulate the activation and function of T cells and B cells (c) suppressor T cells: inhibit the activation and function of both T cells and B cells (d) plasma cells: responsible for the production and secretion of antibodies (e) NK cells: responsible for recognizing abnormal cells and destroying them (f) stromal cells: produce the immune system hormone (cytokine) interleukin-7, which promotes the differentiation of B cells (g) reticular epithelial cells: maintain the blood-thymus barrier, and secrete the thymic hormones that stimulate stem cell division and T cell differentiation (h) interferons: interfere with viral replication inside the cell and stimulate the activities of macrophages and NK cells (i) pyrogens: reset the body's thermostat causing a rise in body temperature (fever) (j) T cells: provide cell-mediated immunity, which defends against abnormal cells and pathogens inside living cells (k) B cells: provide antibody-mediated immunity, which defends against antigens and pathogenic organisms in the body (l) interleukins: enhance nonspecific defenses, and increase T cell sensitivity and stimulate B cell activity (m) tumor necrosis factor: slow tumor growth, and kill sensitive tumor cells (n) colony stimulating factors (CSF): stimulate the production of blood cells in the bone marrow and lymphocytes in lymphoid tissues and organs

13. (1) T cells (thymus-dependent) (2) B cells (bone-marrow derived) (3) NK cells (bone-marrow derived)

14. (1) physical barriers (2) phagocytic cells (3) immunological surveillance (4) interferon (5) complement (6) inflammation (7) fever

Level 2: Reviewing Concepts

15. c
16. d
17. b

18. (1) Specificity: immune response is triggered by a specific antigen, and defends against only that antigen.
(2) Versatility: immune system can differentiate from among tens of thousands of antigens it may encounter during a normal lifetime.
(3) Memory: immune response following second exposure to a particular antigen is stronger and lasts longer.
(4) Tolerance: some antigens, such as those on one's own cells, don't elicit an immune response.

19. - may rupture the cell membrane through the release of perforin.
- may kill the target cell by secreting a poisonous lymphotoxin.
- may activate genes within the nucleus of the cell that tell it to die.

20. The antigen may be destroyed in the following ways: neutralization, agglutination and precipitation, activation of complement, attraction of phagocytes, opsonization, stimulation of inflammation, prevention of bacterial and viral adhesion

21. destruction of target cell membranes, stimulation of inflammation, attraction of phagocytes, enhancement of phagocytosis

22. The injections are timed so that they trigger the primary and secondary responses of the immune system. When first exposed to the hepatitis antigens, B cells produce daughter cells that differentiate into plasma cells and memory B cells. The plasma cells begin producing antibodies, which represent the primary response to exposure. However, the primary response does not maintain elevated antibody levels for long periods, so the second and third injections are necessary to trigger the secondary (anamnestic) response, when memory B cells differentiate into plasma cells and produce a much longer-lasting level in antibody concentrations.

Level 3: Critical Thinking/Clinical Application

23. IgA type antibodies are found in body secretions such as tears, saliva, semen, vaginal secretions, etc., but not in blood plasma. Blood plasma contains IgM, IgG, IgD, and IgE types of antibodies. By testing for the presence or absence of IgA and IgG antibodies, the lab could make a determination as to whether the sample was blood plasma or semen.

24. It would appear that Ted has contracted the disease. Upon initial contact with a virus, the first type of antibody to be produced is the IgM type. The response is fairly rapid, but short-lived. About the time that IgM peaks, IgG levels are beginning to rise. IgG plays the more important role in eventually controlling the disease. The fact that Ted's blood sample has an elevated level of IgM antibodies would indicate that he is in the early stages of a primary response to the measles virus.

25. Although it is certainly possible that the woman suffers from a filarial disease, more likely she suffers from lymphedema resulting from breast surgery. In the procedure known as a radical mastectomy, not only is the cancerous breast removed, but so are the neighboring lymph glands in the axilla and surrounding region. Remember that cancer cells spread by way of the lymphatic system. Removal of the lymph nodes is a precautionary measure to try to prevent this from occurring. The lymph vessels from the arm on the affected side are tied off, as there is no place for the lymph to drain to. Over time this leads to the lymphedema that causes the arm to swell.

26. For Harry's body to produce an immune response to antigen A, the antigen would have to be presented on his MHC proteins on the surface of his cells. For T cells to respond to the antigen, they would have to bind to the MHC complex, which is different in different individuals. Introducing Tilly's cells would not help Harry since they would almost certainly not recognize his MHC complex and would therefore be oblivious to the presence of the antigen. In addition, her cells would be recognized as foreign and would be attacked and destroyed by Harry's macrophages.

27. Since FSH is a protein hormone, it binds to receptors on the surface of its target cells. If you could isolate these receptors, you could inject them into an animal, such as a rabbit, that would give an immune response to the human protein. By isolating the plasma cells from the rabbit that produced antibodies to the FSH receptor, you could clone them to produce large amounts of antibodies. Since each plasma cell produces only one type of antibody, this process would produce what are known as monoclonal antibodies. You could then tag the antibodies with a marker, such as the fluorescent molecule fluorescein so they would be obvious when viewed under a fluorescent microscope. You could then introduce the antibodies into cell populations that you wished to test. If the receptors for FSH were present, the antibodies would bind to them and you could locate them by locating the fluorescent marker.

❑ Media Lab Instructor Notes

Web addresses often change. To avoid dead links, we are listing the keywords in parentheses next the to Web Explorations. Simply go to the Companion Website (http://www.prenhall.com/martini), select the Fifth Edition of Fundamentals of Anatomy and Physiology and search using the key word to locate the current address.

Animations (Website)

- Figure 22-17, 22-18, & 22-19—Animation in play / next format. Antigen recognition and activation (Cytotoxic T cells, Helper T cells, B cells); suitable for lecture demonstration of immune cellular functioning or self-study after presentation.
- Figure 22-16—Animation in play / next format. Antigens and MHC proteins; suitable for lecture demonstration of MHC functions in immunity or self-study tool after presentation.

Web Explorations (Overview)
Web Exploration 1 (**HOMING**)

- *Goal*—review, reinforce concepts
- *Description of page*—2 pages of text with great images, links to other images; by US Army Medical Institute

- *Expectations of student behavior*—read article, view images, depict lymphocyte homing in simple drawing
- *Instructor's role*—introduce lymphocyte homing and travel; guide through links and back
- *Special notes or further uses of exploration*—the back button goes to a homepage with links to the US Army Medical Institute, as well as other A&P topics and photos; there is no page 4—empty link!

Web Exploration 2 (**ALLERGIES**)

- *Goal*—reinforce concepts, ground in daily activities
- *Description of page*—Mayo Clinic health Oasis Java quiz
- *Expectations of student behavior*—read questions, click answers, note new information in responses
- *Instructor's role*—introduce immunity and allergies; tabulate incorrect answers and lead discussions on missed questions
- *Special notes or further uses of exploration*—right side bar FULL of interesting links to other systems

Additional Web Explorations
Should the two explorations found in the text not answer your needs, a third exploration is provided below. Your students do not have direct access to this exploration. You must provide them the address and information in the following paragraph.

Web Exploration 3
Estimated time for completion = 5 minutes

Studying the immune system has led to the development of vaccines. Review in the text the principles of vaccination, paying attention to their mode of action. In developed countries of the world, parents are urged to vaccinate their children to prevent the spread of disease. Many people now feel that this is a dangerous practice and are choosing not to vaccinate. What are the outcomes of a non-vaccinated population? Read the article about **POLIO** at this site (http://www.cdc.gov/epo/mmwr/preview/mmwrhtml/00056989.htm) to learn more about this viruse's recent appearance in Angola. How does the Ministry of Health propose to combat this latest outbreak? Using what you know of the immune system, do you agree with this approach?

Web Exploration 3 (**POLIO**)

- *Goal*—critical thinking, grounding in current events
- *Description of page*—Center for Disease Control Morbidity and Mortality weekly April 1999
- *Expectations of student behavior*—read, take notes, refer to text for vaccination principles
- *Instructor's role*—explain vaccination principles; help students relate knowledge to MOH plan
- *Special notes or further uses of exploration*—bottom of page links to CDC and MMRW; both excellent resources for further inquiry

Topic Outline				A/V Resources				
Objectives	**Chapter 22** **The Lymphatic System and Immunity** (page 1 of 6)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	I. Introduction		5a, 6a					
1a	**II. An Overview of the Lymphatic System**							
	III. Organization of the Lymphatic System	22-1		●	●			●
	A. Functions of the Lymphatic System							
	B. Lymphatic Vessels		5b					
	1. Lymphatic Capillaries	22-2	1a	●	●			
	2. Small Lymphatic Vessels	22-3		●	●			
	3. Major Lymph-Collecting Vessels	22-4		●	●			
1b	C. Lymphocytes		1b					
	1. Types of Lymphocytes		1c					
	2. Life Span of Circulation of Lymphocytes		1d					
	3. Lymphocyte Production	22-5		●	●			
1c	D. Lymphoid Tissues	22-6		●				
	1. MALT	22-6a		●	●			

Objectives	TOPIC OUTLINE **Chapter 22** **The Lymphatic System and Immunity** (page 2 of 6)	Figures	Strategies	A/V RESOURCES Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	2. Tonsils	22-6b	4a	●	●			
	E. Lymphoid Organs							
	1. Lymph Nodes	22-1,4,7	3ab	●	●			●
	2. The Thymus	22-8	1e	●	●			
	3. The Spleen	22-9	1f	●	●			
	F. The Lymphatic System and Body Defenses							
1d	**IV. Nonspecific Defenses**	22-10		●	●			●
	A. Physical Barriers							
	B. Phagocytes		1g					
	1. Microphages							
	2. Macrophages							
	3. Movement and Phagocytosis	3-13a			●			
	C. Immunological Surveillance		1h					
	1. NK Cell Activation	22-11	3c	●	●			

Objectives	Topic Outline **Chapter 22** **The Lymphatic System and Immunity** (page 3 of 6)	Figures	Strategies	A/V Resources: Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	D. Interferons						●	
	E. Complement	22-12	6b	●	●		●	
	1. Complement Activation	22-12		●	●			
	F. Inflammation	22-13	5c	●	●			
	1. The Response to Injury							
	G. Fever							
	V. Specific Defenses: The Immune Response							
	A. Forms of Immunity	22-14		●	●			●
	1. Innate Immunity							
	2. Acquired Immunity							
	B. Properties of Immunity		1j					
	1. Specificity							
	2. Versatility							
	3. Memory		1k					

Topic Outline				A/V Resources				
Objectives	**Chapter 22** **The Lymphatic System and Immunity** (page 4 of 6)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	4. Tolerance		5d					
1f	C. Overview: The Immune Response	22-15		●	●			
	D. T Cells and Cell-Mediated Immunity							
	1. T Cell Activation	22-16	4c	●	●	●		
2a	2. Cytotoxic T Cells	22-17	3d	●	●	●		
2a	3. Suppressor T Cells							
2a	4. Helper T Cells	22-18	11	●	●	●		
1f	E. B Cells and Antibody-Mediated Immunity	22-19		●	●	●		
	1. B Cell Sensitization							
	2. B Cell Activation	22-19		●	●			
2b	3. Antibody Structure	22-20	2a	●	●			
	4. Classes and Actions of Antibodies							
2d	F. Primary and Secondary Responses to Antigen Exposure							

Topic Outline				A/V Resources				
Objectives	**Chapter 22 The Lymphatic System and Immunity** (page 5 of 6)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	1. The Primary Response	22-21a		●	●			
	2. The Secondary Response	22-21b		●	●			
2e	G. Hormones of the Immune System							
	1. Interleukins							
	2. Interferons							
	3. Tumor Necrosis Factors							
	4. Chemicals Regulating Phogocytic Activities							
	5. Colony-Stimulating Factors							
	VI. Summary: The Immune Response	22-22,23,24		●	●			
2f	**VII. The Development of Resistance**							
2g	**VIII. Immune Disorders**							
	A. Autoimmune Disorders							
	B. Immunodeficiency Diseases							
	C. Allergies		6d					

Topic Outline				A/V Resources				
Objectives	**Chapter 22** **The Lymphatic System and Immunity** (page 6 of 6)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	1. Immediate Hypersensitivity	22-25		●	●			
	IX. Stress and the Immune Response							
	X. Aging and the Immune Response							
	XI. Integration with Other Systems	22-26			●			

CHAPTER 23

The Respiratory System

Introduction

An interesting way to get students thinking about this material is to talk about the respiratory problems of premature infants. Many of the students will have had some (probably) indirect experience with such a case. They often know about surfactant but don't have a clear idea what its function is. They may say that it prevents the lungs from collapsing. A good discussion of the whole issue of the pathology of premature infants is discussed in *The Facts of Life* by Harold Morowitz and James Trefil (Oxford University Press, 1992). Another interesting aspect of this subject is the other main problem in premature infants. Their cerebral arteries are fragile and rupture easily when blood pressure rises, as it does immediately after birth. A discussion of this is a nice tie back to the cardiovascular material they just finished.

Instructional Goals/Learning Objectives

1. To discuss the correlation between the histological organization of the respiratory tract and its major functions; note the functional/histological variations along the length of the tract.

    a. *Describe the primary functions of the respiratory system.*
    b. *Explain how the delicate respiratory exchange surfaces are protected.*
    c. *Identify organs of the upper and lower respiratory systems and describe their functions.*
    d. *Describe the physical principles governing the movement of air into the lungs and the diffusion of gases into and out of the blood.*
    e. *Describe the actions of the respiratory muscles.*

2. To emphasize the functional interchange between pulmonary ventilation and external, internal and cellular respiration.

    a. *Differentiate between pulmonary ventilation and alveolar ventilation.*
    b. *Describe how oxygen and carbon dioxide are transported in the blood.*

3. To introduce the major gas laws and detail their physiological significance.

4. To discuss the role of the respiratory system in maintaining homeostasis, to describe the homeostatic mechanisms involved, and to relate homeostatic malfunctions to important clinical conditions.

    a. *Describe the various factors that control the rate of respiration.*
    b. *Identify and discuss the reflex activity and the brain centers involved in the control of respiration.*

❑ Teaching Strategies

1. Analogies

a. The structures of the respiratory mucosa work like the air filter in a car or the lint trap in a dryer, catching debris that would be harmful to the engine or motor should it get inside. The air filter of a car can be removed and replaced with a clean one, not so easily done in the respiratory tract! Hence there must be a mechanism to keep the filter from accumulating debris. The mucus escalator acts like a conveyor belt, moving the trapped particles up to the esophageal opening where they can be swallowed, or to the pharynx to be removed by a sneeze or a cough.

b. The pharynx is like a large room, extending from the internal nares to the beginning of the lower respiratory system, the larynx. If you were standing in that room, you could walk down into the larynx, ventrally into the mouth, or superiorly into the nasal cavity. As you headed up toward the internal nares, you could even take a left or right turn and work your way up to the middle ear. If you went straight into the nose, you could work your way through the meatus between the conchae and into the sinuses of the ethmoid and maxilla.

c. Compare the alveolar sacs to clusters of grapes. Have the students imagine what the grapes would look like if the pulp was removed, but the skin was left intact. The large stem of the entire grape cluster would be analogous to the small bronchioles, which extend into smaller "terminal" branches leading to 3 or 4 small clusters. The terminal branches lead to even smaller "respiratory" branches at the level of the individual clusters, each containing several grapes. This cluster is analogous to the alveolar sac, and every grape has its own stem (the alveolar duct). The appearance of the alveoli surrounded by the elastic fibers and capillaries are like the grapes as they appear in the grocery store, still wrapped in the net bag.

d. The exchange of oxygen from the alveolus to the pulmonary capillary with carbon dioxide from the capillary to the alveolus must occur at the same time, like tennis players on either side of the net serving at the same time. But, unlike the tennis players, the air in the alveolus and blood in the capillary are not standing still. They are moving in opposite directions. Imagine the tennis players running across court from opposite sides, and serving the ball over the net when they get abreast of each other. Another representative image can be described: imagine passengers on two different trains that are traveling in opposite directions. When the trains get side-by-side on the tracks, passengers from Train A jump across the space into the opened doors of Train B. At the same time, passengers from Train B jump to Train A (what a mess if there is a mid-air collision!).

e. Describe the surface tension that exists within the alveoli as the same kind of tension that makes it difficult to pull apart two pieces of wet glass or two pieces of plastic wrap. Not only are they difficult to separate, but if the surfaces get close enough, they'll be drawn toward each other. The surfactant reduces the attraction established by the surface tension.

f. Before introducing the specifics regarding pressure and air flow during inhalation and exhalation, draw a simple analogy on the board: draw a container with an opening. On the outside, write "HIGH PRESSURE." On the inside, write "LOW PRESSURE." Ask the students to tell you in what direction the air will move (OUT-IN). Now reverse the labels, making the outside the low pressure area, and the inside the high pressure area. Ask the same question (IN-OUT). Now label the inside and outside as "EQUAL PRESSURE." Tell the students that you still want to get the air to move from out to in, or vice versa. How might that be accomplished? If they seem to be stumped, give them the following hint: "Boyle's Law." Try to get them to come to the conclusion that you could change the size of the container and accomplish the same task. If you squeeze it, decreasing its size, then the pressure inside becomes higher than the pressure outside, and air rushes out. If you stretch the walls it gets bigger, then the pressure inside becomes lower than the pressure outside, and air rushes in. Explain that if the purpose of pulmonary ventilation is to get the atmospheric air into and out of the lungs, then to accomplish that we can either 1) increase and decrease the pressure of the air in the room around us (not very practical) OR 2) increase and decrease the volume of the container (the lungs). But of course, there is no way to physically grab the surface of the lungs (the visceral membrane) in order to stretch it out or squeeze it in. To do that, we must rely on the parietal pleura. By adhering to the visceral membrane it will "suck" or "squeeze" on the visceral surface of the lung. How do we get the parietal membrane to do that? What is the parietal membrane attached to? The thoracic wall that makes up the thoracic cavity. So, if we can change the size of the thoracic cavity, the parietal membrane will be a part of that changing container and will "suck" or "squeeze" the visceral membrane. Hence, changing the size of the thoracic cavity will change the size of the lung, and as the volume of the lung changes, air will move in or out.

2. Demonstrations

a. Have the students rub their tongues along the roof of their mouths to feel the ridges of the hard palate and the cushier soft palate further back, which ends with the little "hangy-down thing," the uvula.

3. Vocabulary Aids

a. Associate the "L" in lower with the "L" in larynx. The larynx is lower than the pharynx. Many students mispronounce these two words by inserting an "n" before the "y." The result is "fair ninks" instead of "fair inks."

b. The thyroid cartilage is named because of the thyroid gland located on its anterior surface. While its anterior surface is quite large, it does not completely surround the larynx. Associate the "T" in Thyroid with the "T" in Top. The thyroid cartilage is the one on top.

c. The word "cricoid" means "ring-like." It is the cartilage that makes a complete ring around the larynx. It enlarges on the dorsal surface even though it looks small from the front.

d. A doctor using a tongue depressor to examine your throat and telling you to say

"AHHH," is an example of phonation. There is no word produced, just sound. On the other hand, if you mouth a word, as if you were lip-synching, then you are articulating. Both phonation and articulation must occur for there to be intelligible sound.

e. Tidal volume ebbs and flows, like the tide of the ocean. It can also be associated with the type of breathing done if someone is sitting quietly and watching TV.

4. Applications

a. Point out that the lungs are involved in pH control. The connection between pH and the respiratory system is carbon dioxide. The amount of carbon dioxide in the blood has a direct effect on the pH of the blood.

b. No doubt students have heard references made to "upper" or "lower" respiratory infections, but may not be aware of the anatomical margins of each.

c. It is the extensive vascularization within the nasal cavity and thin mucosa that makes it vulnerable to chemicals being absorbed across the surface, like cocaine, which can be the cause of epistaxis (nosebleeds).

d. Have the students think about what happens to their tongue while swallowing. Most do not realize how far back their tongue extends. Let them watch someone else swallow, while they observe the elevation of the larynx. Point out that it is physically impossible to swallow and inhale at the same time.

e. Smoking destroys the alveolar membranes and the elastic tissue, thus reducing surface area and the recoil action needed for expiration. The disease that develops is called emphysema.

5. Common Student Misconceptions/Problems

a. Most students have some prior understanding about the respiratory system with respect to its anatomy and to the process of ventilation. However, they frequently equate respiration with breathing. Although they have been taught about cellular respiration, the average student has not necessarily made the connection between the two processes.

b. Students often do not realize that the pharynx is a cavity or space as opposed to a structure. It is also amazing for them to discover how connected everything is, the nose, ears, paranasal sinus, respiratory tract, and digestive tract. Point out that when one gets a sore throat, it often develops into an ear infection, cough, or sinus infection

c. Even though the word "larynx" sounds like the word "pharynx," it is a structure and not a space, though it is hollow and the opening is called the glottis. The larynx is what we call the "Adam's apple."

d. The consistency of the lung is difficult for students to picture. Compare the texture of

the lungs to soap lather or bubble bath foam. The bubbles represent the alveoli. Looking at the cut surface of a lung is like looking at the cut surface of a piece of bread, it is full of tiny holes.

e. Students often confuse terminal and respiratory bronchioles, since "terminal" implies that they should be at the end. Point out that terminal bronchioles mark the end of the conduction zone, while respiratory bronchioles represent the beginning of the respiratory zone, where gas exchange takes place.

f. Although there is reference to a cavity existing between pleural and parietal membranes, in the lungs those membranes touch, so there is no actual space (unless atelectasis occurs).

g. Students' dread of physics is almost as extreme as their dread of mathematics, and many introductory A &P students have not taken physics in high school. Try to use some everyday occurrences to illustrate the Gas Laws. Ask the students what would happen if you were to try to crush a closed can of soda. A certain amount of pressure exists in the can due to the carbonation (big container/small pressure). If you try to make the can smaller by squeezing it, the pressure inside increases as the molecules have less room to bounce around (small container/big pressure). If you keep squeezing, the pressure increases beyond the ability for the can to hold it in, and there is an explosion. Heating the can would have the same effect, since that would increase the collision frequency. That is why the labels of aerosol cans always warn against incinerating. Another practical example of Boyle's Law is what happens when you open a can of soda-there is a small release of pressure that you hear as a phttt! sound. When the can is closed the pressure inside is high (small container/big pressure), but as soon as the can is opened, some of the gas is released into the larger "container" of the room and the pressure in the can is reduced (big container/small pressure). If you shake the can, increasing the collision frequency of the gas molecules, the pressure inside the small, closed can increases. If you now open the can, the release of that increased pressure is so strong that it brings the soda with it! One final example of the inverse relationship between volume and pressure can be seen with the power water guns that were so popular a few years ago. In this case, the volume of the water container stays the same, but as the user pumps more air into the closed container, the pressure increases (small container/big pressure). If the water container was an expandable balloon, and it increased in size as the user pumped, the pressure inside would remain low (big container/small pressure).

h. While the concept of hemoglobin saturation does not seem difficult to understand for most students, the saturation curve is somewhat of an enigma. It is important for them to comprehend the curve, so that they will understand why control mechanisms in the medulla rely on pCO_2 and NOT pO_2. Point out that when pO_2 is its lowest, it rarely gets below 60 mmHg. At its highest, it is at 100 mmHg. Examining the curve, that means we operate almost exclusively "in the flat part" with saturation ranging from 80 mmHg to 100 mmHg. Even changes in pH, pCO_2, and temperature do not change the shape significantly. However, should the pO_2 drop to 40 mmHg, saturated oxyhemoglobin rapidly becomes unsaturated and loses its oxygen carrying ability. Hence, pO_2 is the most significant factor in the saturation of Hb, but it is not the most

significant factor for turning on our "alarm system."

It is frustrating that the students are reluctant to let go of this misconception, no matter what you say. For example, you ask why swimmers hyperventilate before diving into the pool, many students will tell you that hyperventilation brings in more oxygen, and so the swimmer can go longer without having to breath. Compare the mechanism to a fire alarm. What would be a better alarm system: one that is triggered as soon as smoke is detected, or one that buzzes as soon as the plastic casing melts? Explain that if pO_2 is no lower than 50 or 60 mmHg, our alarm doesn't go off, but if we wait for it to get low enough to trigger the alarm, it may already be too late.

6. Lecture ideas

a. Consider introducing the respiratory system with the following dialogue (student-anticipated responses are in Italics):

"Can someone tell me what the function of the respiratory system is?"
"It lets you breath in air."
"What do you mean by air?"
"You, know...oxygen"
"What else?"
"It also lets you breath out carbon dioxide."
"Okay. Let's write that down (on the top of the board): A function of the respiratory system is to enable us to move oxygen from the atmosphere to our lungs and move carbon dioxide from our lungs to the atmosphere. "Well, why do we need oxygen?"
"You need oxygen to live."
"What do you mean; that is, why do you need oxygen to live; where is it used?"
"Well, the cells need oxygen."
"What do the cells do with the oxygen?"
"They use it during aerobic glycolysis."
"What about the carbon dioxide? Where does that come from?"
"It is produced during glycolysis."
"Okay. Let's write that down (on the board, at a distance below the first statement): Cells use oxygen and produce carbon dioxide during glycolysis. Now, don't you think there might be a connection between these two statements? (PAUSE). Does it sound logical that the respiratory system might have a role in that connection? (PAUSE). Maybe another function of the respiratory system is to get the oxygen to the cells and carbon dioxide from the cells? (PAUSE TO LET THAT SINK IN). Let's add that to our list (just above the glycolysis statement): A function of the respiratory system is to get oxygen and carbon dioxide to and from cells (with the help of the circulatory system). "Let's go back to the lungs. Is the oxygen that you inhale really inside your body? That is, is being in the lung the same thing as being in the body?"

(IF THE STUDENTS REMEMBER THE DIFFERENCE BETWEEN INSIDE AND OUTSIDE DISCUSSED IN CHAPTER 4, THEY WILL REALIZE, HOPEFULLY, THAT BEING IN THE ALVEOLI IN THE LUNG IS NOT THE

SAME AS BEING IN THE BLOOD).
"So as we look at our list, keeping in mind that supplying the cell with oxygen is our goal, we have 1) oxygen moving from the atmosphere to the lungs, and carbon dioxide moving from the lungs to the atmosphere; 2) oxygen moving from the blood to the cells and carbon dioxide moving from the cells to the blood. What do we need to add to our list to make the picture complete?"
"The oxygen has to get from the lungs to the blood, and the carbon dioxide has to get from the blood to the lungs."
"Exactly."

b. Ask the students to hypothesize why the cartilage rings of the trachea do not go all the way around. (location of the esophagus)

c. As you describe the structural differences of the left and right bronchi, ask the students to determine why they are not symmetrical. (location of the heart)

d. As you describe the affect of the ANS on the smooth muscle layer of the bronchioles, emphasize the "logic" of the effects of stimulating the different divisions of the ANS. That is, if someone is "resting and digesting" (PSNS), he/she will be breathing quietly, and there will be less demand on the air flow in the lungs. On the other hand, if that same person is "fighting or fleeing" (SNS), then the air flow will need to increase to meet the demands of increased oxygen consumption. Remind the students that in order to have bronchoconstriction, the PSNS causes the smooth muscle to contract (stimulates activity). In order to have bronchodilation, the SNS causes the smooth muscle to relax (inhibits activity). This is the reverse of what the students might recall, since they generally associate activation of the SNS with increased activity. Remind them that this is the same sympathetic effect seen in the blood vessels going to skeletal muscles.

e. Clinically, it is important to be able to measure how much air is moved in and out of the lungs during a single cycle of quiet breathing (Tidal Volume). However, since breathing is a dynamic process, it is more meaningful to examine what happens to the respiration process over a period of time. Hence, the respiratory minute volume takes both volume and time into consideration. If an individual's tidal volume was 500ml, and he breathed 12 cycles each minute, then the respiratory minute volume could be 6 liters. Write the equation on the board, so that it is more obvious that respiratory minute volume can be increased or decreased if either tidal volume or respiratory rate is increased or decreased.

f. Ask the students to imagine that they are sitting quietly watching TV, participating in some Tidal Volume breathing. Their roommate walks in and drops an ice cube down their back. What do they do? That is ERV. If, on the other hand, someone slapped them on the back, making them exhale forcefully, that's IRV.

g. As you examine Figure 23-20, point out that the alveoli will have more oxygen than carbon dioxide; i.e., high pO_2 and low pCO_2. The arterioles bringing blood to the capillaries in the lungs will have less oxygen then the venules leaving the pulmonary capillaries, so the pO_2 is lower than the pCO_2. The reverse is true in the systemic

circulation. Its arterioles will feed capillaries with blood that has a high pO_2 and a low pCO_2. The tissues, on the other hand, will be going through glycolysis, so the pCO_2 will be larger than the pO_2. In summary:

Location	pO_2	pCO_2
alveolar space	high	low
lung capillaries	low	high
systemic capillaries	high	low
tissue cells	low	high

Stress that since gases move down their pressure gradients, and act independently (Dalton's Law), it is the partial pressure differences that drive oxygen from the space into the blood and carbon dioxide from the blood into the space. The reverse happens at the level of the tissues. As long as the difference exists, the gases will move as described. An increase or decrease of the differences will affect the rate of the diffusion and how much of the gas is dissolved (Henry's Law).

h. Write the reaction for the oxidation of hemoglobin on the board, emphasizing that it is reversible. It is helpful to write the reaction as two steps, so as you describe the effects of pO_2, CO, pH, temperature, and DPG, you can illustrate the direction in which the reaction is driven-to form HbO (in pulmonary capillaries) or to form HHb (in tissue capillaries). Include the hydrogen ion, so you will be able to refer to it during the discussion of pH.

$$HHb + O_2 \Rightarrow HbO_2 + H^+ \Rightarrow HHb + O_2$$

pulmonary capillary — blood — tissue capillary

i. As you describe the Bohr effect, it might be easier for the students to visualize the role of H^+ concentration if you spread the reaction out to include the dissociation of the weak acid, carbonic acid. With the full equation, you can emphasize that as $C0_2$ increases, pH drops.

$$CO_2 + H_2O \Rightarrow H_2CO_3 \Rightarrow HCO_3^- + H^+$$

j. Since the pCO_2 is so low, only a small percentage is dissolved in the plasma (Henry's Law); however, most of the CO_2 is transported in the plasma in the form of the bicarbonate ion, which moves from the RBC to the plasma during the chloride shift.

❑ Answers to End of Chapter Exercises

Level 1: Reviewing Facts and Terms

1. a
2. c
3. d
4. c
5. c
6. d
7. b
8. c
9. a
10. b
11. a
12. c

13. (1) Provide an extensive area for gas exchange between air and circulating blood. (2) Move air to and from the exchange surfaces of the lungs. (3) Protect respiratory surfaces from dehydration, temperature changes, or other environmental variations and defend the respiratory system and other tissues from invasion by pathogenic microorganisms. (4) The production of sounds involved in speaking, singing, or non-verbal communication. (5) Provide olfactory sensations to the CNS from the olfactory epithelium in the superior portions of the nasal cavity. (The respiratory system also assists indirectly in the regulation of blood volume, blood pressure and the control of body fluid pH.)

14. The upper respiratory system consists of the nose, nasal cavity, paranasal sinuses, and pharynx. The lower respiratory system includes the larynx, trachea, bronchi, bronchioles and alveoli of the lungs.

15. (1) Goblet cells in the epithelium and mucous glands in the lamina propria of the respiratory tract produce a sticky mucus that bathes exposed surfaces. (2) In the nasal cavity, cilia sweep mucus and any trapped debris or microorganisms toward the pharynx, where it will be swallowed and exposed to the acids and enzymes of the stomach. (3) In the lower respiratory system, the cilia beat toward the pharynx, creating a mucus escalator that cleans the respiratory passageways. (4) Filtration occurs in the nasal cavity. (5) Particles may become trapped in the liquid covering the alveolar surfaces. (6) Foreign particles can be engulfed by alveolar macrophages.

16. (a) The nasopharynx, the superior portion, is the region where the nasal cavity opens into the pharynx. (b) The oropharynx, the middle portion, is the region where the mouth opens into the pharynx. (c) The laryngopharynx, the inferior portion, is the region where the larynx opens into the pharynx.

17. During swallowing, the larynx is elevated, and the epiglottis folds back over the glottis, preventing the entry of liquids or solid food into the respiratory passageways.

18. The parietal pleura covers the inner surface of the thoracic wall and extends over the diaphragm and mediastinum. The visceral pleura covers the outer surfaces of the lungs, extending into the fissures between the lobes.

19. (1) pulmonary ventilation (breathing) (2) gas diffusion across the respiratory membrane (3) the storage and transport of oxygen and carbon dioxide (4) the exchange of dissolved gases between the blood and the interstitial fluids.

20. increased respiratory rate, increased heart rate, and elevated hematocrit.

21. (1) CO_2 is converted to carbonic acid (2) CO_2 is bound to the hemoglobin of red blood cells (3) CO_2 is dissolved in the plasma

22. When the P_{CO2} goes up, the bronchioles increase in diameter, a process called bronchodilation. When the P_{CO2} declines, the bronchioles constrict (bronchoconstriction). Airflow is therefore directed to lobules where the P_{CO2} is high, which helps improve gas exchange, because these will also be the lobules where the P_{O2} is very low.

Level 2: Reviewing Concepts

23. a
24. a
25. d
26. d
27. c
28. d
29. b

30. With less cartilaginous support, the amount of tension in the smooth muscles has a greater effect on bronchial diameter and the resistance to air flow.

31. During talking, the airways are open and the food passages are closed. Trying to swallow while talking is therefore likely to lead to inadvertant entry of food particles into the airways, which will then trigger coughing to expel the food.

32. The nasal cavity is designed to cleanse, moisten, and warm inspired air, whereas the mouth is not. Air entering through the mouth is drier, and as a result can irritate the trachea, causing soreness of the throat.

33. The walls of bronchioles, like the walls of arterioles, are dominated by smooth muscle tissue. Varying the diameter of the bronchioles (bronchodilation, bronchoconstriction), provides control over the amount of resistance to airflow and the distribution of air within the lungs, just as vasodilation and vasoconstriction of the arterioles regulates blood flow/distribution.

34. The septal cells produce surfactant that reduces surface tension in the fluid coating the alveolar surface. The alveolar walls are very delicate, and without surfactant the surface tension would be so high that the alveoli would collapse.

35. The differences in partial pressure are substantial. The diffusion distances involved are small. The gases are lipid soluble. The total surface area is large. Blood flow and air flow are coordinated.

36. Pulmonary ventilation is the physical movement of air in and out of the respiratory tract. The primary function of pulmonary ventilation is to maintain adequate alveolar ventilation. Alveolar ventilation is air movement into and out of the alveoli. Alveolar ventilation prevents the buildup of carbon dioxide in the alveoli and ensures a continual supply of oxygen that keeps pace with absorption by the bloodstream.

37. a) Boyle's Law describes the inverse relationship that exists between pressure and volume: if you decrease the volume, pressure rises; if you increase the volume the pressure falls. b) Dalton's Law states that each of the gases that make up a mixture contribute to the total pressure in proportion to its relative abundance i.e., all of the partial pressures added together equal the total pressure exerted by the gas mixture. c) Henry's Law states that, at a given temperature, the amount of a particular gas that dissolves in a liquid is directly proportional to the partial pressure of that gas.

38. An injury to the chest wall that penetrates the parietal pleura or damages the alveoli and the visceral pleura can allow air into the pleural cavity. This pneumothorax breaks the fluid bond between the pleurae and allows the elastic fibers to recoil, causing the lung to collapse (atelectasis).

39. Sneezing and coughing both involve a temporary cessation of respiration (apnea).

40. Pulmonary volumes include:

a) resting tidal volume - average 500 ml
b) expiratory reserve volume - approximately 1200 ml
c) residual volume - averages 1200 ml
d) minimal volume - 30-120 ml
e) inspiratory reserve volume - approximately 3600 ml

These values are determined experimentally and the values are useful in diagnosing problems with pulmonary ventilation.

Respiratory capacities include:

a) inspiratory capacity
b) functional residual capacity
c) vital capacity
d) total lung capacity

Respiratory capacities are determined by adding the values of various volumes.

41. The effect of pH upon the hemoglobin saturation curve is called the Bohr effect. When the partial pressure of CO_2 rises, the pH drops; when the partial pressure of CO_2 declines, the pH rises. Hemoglobin molecules release more oxygen when the pH drops than they

would when the pH rises. Hydrogen ions tend to "bump" oxygen molecules from the heme units. As the temperature rises, hemoglobin releases more oxygen; as the temperature declines, hemoglobin holds oxygen more tightly. For any partial pressure of oxygen, the higher the concentration of BPG, the more oxygen will be released by the hemoglobin molecules.

42. The DRG is the inspiratory center that contains neurons that control lower motor neurons innervating the external intercostal muscles and the diaphragm. The DRG functions in every respiratory cycle, whether quiet or forced. The VRG functions only during forced respiration, i.e., active exhalation and maximal inhalation. The neurons involved with active exhalation are sometimes said to form an expiratory center.

43. chemoreceptors sensitive to the P_{CO2}, pH, and/or P_{O2} of the blood or cerebrospinal fluid; changes in blood pressure in the aorta or carotid sinuses; stretch receptors that respond to changes in the volume of the lungs; irritating physical or chemical stimuli in the nasal cavity, larynx or bronchial tree; pain, changes in body temperature, and abnormal visceral sensations

Level 3: Critical Thinking/Application

44. AVR = respiratory rate X (tidal volume – dead air space). In this case the dead air space is 200 ml (the anatomical dead air space plus the volume of the snorkel), therefore AVR = respiratory rate X (500 ml - 200 ml). Since we want to maintain an AVR of 6.0 L/min (6.0 L/min = respiratory rate X 300 ml), then respiratory rate = 6.0 L/min divided by 300 ml or 20 breaths/min.

45. An increase in ventilation will increase the movement of venous blood back to the heart (recall the respiratory pump). This would increase venous return and thus help to increase blood pressure (Starling's law of the heart).

46. A person suffering from chronic emphysema has constantly elevated levels of carbon dioxide in the blood, due to an inability to eliminate carbon dioxide efficiently as a result of the physical damage to the lungs. Over time, the brain ignores the stimulatory signals produced by the increased carbon dioxide and begins to rely on information from the peripheral chemoreceptors to set the pace of breathing (in other words, accommodation has occurred). The peripheral chemoreceptors also accommodate to the elevated carbon dioxide, and respond primarily to the level of oxygen in the blood, increasing breathing when oxygen levels are low and decreasing breathing when oxygen levels are high (this is called hypoxic drive). When pure oxygen was administered, chemoreceptors responded with fewer action potentials to the medulla, and Mr. B. stopped breathing.

47. While you were sleeping, the air that you were breathing was so dry it absorbed more than the normal amount of moisture as it passed through the nasal cavity. The loss of moisture made the mucous secretions quite viscous and harder for the cilia to move. Your nasal epithelia continued to secrete mucus, but very little of it moved. This ultimately produced the nasal congestion. After the shower and juice, more moisture was transferred to the mucus, loosening it and making it easier to move, thus clearing up the problem.

48. A person suffering from kyphosis has an abnormal thoracic curvature of the spine. The abnormal curvature interferes with rib movement during ventilation, as well as lung expansion. As a result, the lungs cannot expand to their full potential. This would decrease the inspiratory reserve and possibly the tidal volume, thus leading to a decreased vital capacity.

49. In anemia, the decreased ability of blood to carry oxygen is due to the lack of functional hemoglobin, red blood cells, or both. The disease does not interfere with the exchange of carbon dioxide within the alveoli nor with the amount of oxygen that will dissolve in the plasma. Since the chemoreceptors respond to dissolved gases and pH, as long as the concentrations of dissolved carbon dioxide, oxygen, and pH are normal, there should be no significant change in ventilation patterns.

50. The obstruction in Doris' right lung would not allow for gas exchange. Thus the blood moving through the right lung would not oxygenate and would retain carbon dioxide. The retention of carbon dioxide in the blood would lead to a lower pH than the blood leaving the left lung. The lower pH will shift the oxygen-dissociation curve to the left (Bohr effect) for the right lung, compared to the left lung.

❑ Media Lab Instructor Notes

Web addresses often change. To avoid dead links, we are listing the keywords in parentheses next the to Web Explorations. Simply go to the Companion Website (http://www.prenhall.com/martini), select the Fifth Edition of Fundamentals of Anatomy and Physiology and search using the key word to locate the current address.

Animations (Website)

- Figure 23-9 & 23-11—Animation in play / pause format. The bronchi and lobules of the lung continuing into alveolar organization; suitable for lecture demonstration of lower respiratory anatomy or self-study.
- Figure 23-19—Animation in play / next format. An overview of respiratory processes and partial pressure in respiration; suitable for lecture demonstration of external / internal respiration or self-study tool after presentation.
- Figure 23-24—Animation in play / next format. A summary of the primary gas transport mechanisms; suitable for lecture demonstration of gas transport or self-study tool after presentation.

Animations (CD-ROM)

- Rotating 3-dimensional image of respiratory system corresponding to Figure 23-1 Components of the respiratory system.

Web Explorations (Overview)

Web Exploration 1 (**ASTHMA**)

- *Goal*—critical thinking, concept review
- *Description of page*—JAMA medical news and perspectives June 16, 1999
- *Expectations of student behavior*—read article, note theories, discuss personal theories
- *Instructor's role*—explain asthma, discuss "theory" and epidemiology
- *Special notes or further uses of exploration*—links to other JAMA articles and points of interest

Web Exploration 2 (**SURFACTANT**)

- *Goal*—critical thinking; current events
- *Description of page*—Eurekalert UC Santa Barbara research release
- *Expectations of student behavior*—read article, prepare outline, review text for uses
- *Instructor's role*—discuss surfactant role, assist in understanding implications of article
- *Special notes or further uses of exploration*—internal links to research lab information, home page links to medical resources, news releases, other web sites

Additional Web Explorations

Should the two explorations found in the text not answer your needs, a third exploration is provided below. Your students do not have direct access to this exploration. You must provide them the address and information in the following paragraph.

Web Exploration 3

Estimated time for completion = 10 minutes

Respiratory physiology can seem quite complicated. To visualize the processes involved in pulmonary ventilation, go to this website (http://omie.med.jhmi.edu/res_phys/StaticsTutorial/01StaticsTut.HTML). Here you will find a series of interactive pages with descriptions and graphs of pulmonary pressures to help in your understanding. As you work through these pages, keep notes on the information you are learning. You may want to work in groups so that you can discuss the information as you work.

Web Exploration 3 (**PULMONARY VENTILATION**)

- *Goal*—review, enhancement of lecture content
- *Description of page*—Johns Hopkins School of Medicine Interactive Respiratory Phys series
- *Expectations of student behavior*—read, click through, write periodically
- *Instructor's role*—demonstrate page, explain pressures and lung volumes, assist in understanding
- *Special notes or further uses of exploration*—long series (use the "enough button!"); links go to dictionary, site links to labs and other tutorials in respiratory physiology

Topic Outline				A/V Resources				
Objectives	**Chapter 23 The Respiratory System** (page 1 of 5)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	I. Introduction		5a, 6a					
1a	**II. Functions of the Respiratory System**		4a					
1c	**III. Organization of the Respiratory System**	23-1	3a, 4b	●	●	●	●	●
	A. The Respiratory Mucosa	23-2	1a	●	●			●
	1. The Respiratory Defense System	4-22, 23-2c		●	●			●
1b	**IV. The Upper Respiratory System**	23-1,3		●	●			●
	A. The Nose and Nasal Cavity	7-3d,14 23-3	2a	●	●			●
	1. The Nasal Mucosa							
	B. The Pharynx	23-3c	1b, 5b	●	●			
	V. The Larynx	23-4		●	●			
	A. Cartilages and Ligaments of the Larynx	23-4,5	3ac, 4d, 5c	●	●			
	1. Sound Production		3d					
	B. The Laryngeal Musculature							
	VI. The Trachea	23-6, 2a	6b	●	●			●

Objectives	TOPIC OUTLINE **Chapter 23** **The Respiratory System** (page 2 of 5)	Figures	Strategies	A/V RESOURCES Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	VII. The Primary Bronchi	23-6, 7	6c	●	●			●
	VIII. The Lungs	23-7	5d	●	●			●
	A. Lobes and Surfaces of the Lungs	23-7,8		●	●			●
	B. The Bronchi	23-6a,9,10		●	●	●		●
	C. The Bronchioles	23-10b	6d	●	●			●
	1. Pulmonary Lobules	23-10		●	●			●
	D. Alveolar Ducts and Alveoli	23-10b,11,12	1c, 5e	●	●	●		●
	E. The Blood Supply to the Lungs	21-23,24,26		●	●			
	IX. The Pleural Cavities and Pleural Membranes	23-8	5f	●	●			
	X. Respiratory Physiology	23-13		●	●			
1d	A. Pulmonary Ventilation							
3	1. Gas Pressure and Volume (Boyle's Law)	23-14	5g	●	●			
	2. Pressure and Airflow to the Lungs	23-15	1f	●	●			
	3. Pressure Changes during Inhalation and Exhalation	23-16ab		●	●			

Objectives	TOPIC OUTLINE **Chapter 23** **The Respiratory System** (page 3 of 5)	Figures	Strategies	A/V RESOURCES: Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	4. The Respiratory Cycle	23-16	3e	●	●			
1e	5. Respiratory Muscles	11-11,12,14,15 23-17		●	●			
	6. Modes of Breathing							
	7. Respiratory Rates							
	8. The Respiratory Minute Volume		6e					
	9. Alveolar Ventilation							
2a	10. Relationships among V_T, V_E and V_A							
	11. Respiratory Performance and Volume Relationships	23-18	6f	●	●			
	B. Gas Exchange at the Respiratory Membrane						●	
3	1. Dalton's Law and Partial Pressures							
3	2. Diffusion between Liquids and Gases (Henry's Law)	23-19		●	●	●		
	3. The Composition of Alveolar Air							

Objectives	TOPIC OUTLINE **Chapter 23** **The Respiratory System** (page 4 of 5)	Figures	Strategies	A/V RESOURCES Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	4. Diffusion at the Respiratory Membrane							
	5. Partial Pressures in Alveolar Air and Alveolar Capillaries	23-20		●	●			
	6. Partial Pressures in the Systemic Circuit	23-20b	6g	●	●			
2b	C. Gas Pickup and Delivery						●	
	1. Oxygen Transport	23-21, 22, 23	5h, 6hi	●	●			
	2. Carbon Dioxide Transport	23-24	6g	●	●			
	D. Summary: Gas Transport	23-25		●	●	●		
4a	**XI. Control of Respiration**							
	A. Local Regulation of Gas Transport and Alveolar Function							
	B. The Respiratory Centers of the Brain							
	1. Respiratory Centers in the Medulla Oblongata	23-26		●	●			
4b	2. The Apneustic and Pneumotaxic Centers	23-27		●	●			

Objectives	TOPIC OUTLINE			A/V RESOURCES				
Objectives	**Chapter 23** **The Respiratory System** (page 5 of 5)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	3. Respiratory Reflexes							
	4. The Chemoreceptor Reflexes	23-28b		●	●			
	5. The Baroreceptor Reflexes							
	6. The Hering-Breuer Reflexes							
	7. Protective Reflexes							
	8. Other Sensations That Affect Respiratory Function							
	C. Voluntary Control of Respiration							
	XII. Changes in the Respiratory System at Birth							
	XIII. Aging and the Respiratory System	23-29			●			
	XIV. Integration with Other Systems	23-30			●			

CHAPTER 24

The Digestive System

❑ Introduction

The liver is a fascinating organ that usually gets little attention. Two recent articles about the liver provide interesting applications that can be used to get students attention. The first, Alcohol and the Liver, by Achord (*Scientific American Science and Medicine*, March/April 1995) discusses the toxicity of alcohol to the liver. You can begin with a dramatic image of advanced ascites in an advanced alcoholic. This leads to the obvious questions, "Why is the abdomen so swollen?" and "Why is alcohol toxic?" The answers to both questions provide many opportunities for good discussion. The article has some very nice illustrations of liver histology and how it changes with pathology. The second article (*Scientific American Science and Medicine*, May/June 1995) follows nicely from the first. It describes recent advances in production of an artificial liver. The authors, Sussman and Kelly, discuss the history and technical problems encountered in producing an effective artificial liver. Students are interested, in general, in artificial organs. The problems in producing such devices often are a good illustration of the principles of function of the organ.

❑ Instructional Goals/Learning Objectives

1. Introduce the components and functions of the digestive system.

   a. *Identify the organs of the digestive tract and the accessory organs of digestion.*
   b. *List the primary functions of the digestive system.*
   c. *Describe the histological characteristics of a representative portion of the digestive tract and relate anatomical structure to specific digestive functions.*
   d. *Describe processes involved in the movement of digestive materials through the gastrointestinal tract.*
   e. *List and describe the mechanisms that regulate the activities of the digestive system.*
   f. *Describe the anatomy and functions of the oral cavity, pharynx, and esophagus.*
   g. *Detail the stomach's anatomy, histology, and its roles in digestion and absorption.*
   h. *Describe the anatomical and histological characteristics of the small intestine.*
   i. *Explain functions of the intestinal secretions and discuss the secretory regulation.*
   j. *Describe the structure and functions of the pancreas, liver, and gall bladder and explain how their activities are regulated and coordinated.*
   k. *Discuss the regulation and coordination of gastric and intestinal movements, gastric emptying, and intestinal absorption.*
   l. *Describe the structure of the large intestine, its movements, and the absorptive processes that take place within it.*
   m. *Describe digestion and absorption processes for carbohydrates, lipids, and proteins.*
   n. *Discuss the mechanisms and processes involved in the absorption of water, electrolytes, and vitamins.*

☐ Teaching Strategies

1. Analogies

a. The hormonal and neural responses that occur along the length of the digestive tract help to orchestrate the movement and digestion of the chyme as it travels from one area to the next. Imagine the chyme traveling from room to room down the digestive tract. As it enters a room, its presence sets off a series of events that will aid in the mechanical and chemical digestion process. As it opens the door and turns on the lights to the next room, it closes the door and turns off the lights of the room behind it; that is, when it leaves a room to enter the next, a whole new series of events takes place, including inhibiting activity of where it's been and stimulating activity of where it's going. The movement is continuous so that the exit from one room often overlaps with the entrance into the next.

b. As the pancreas sits, "cradled" in the arms of the duodenum, its chunky, lumpy appearance is a result of the acinar arrangement of its cells. The acini resemble balloons with hollow strings attached. The wall of each balloon is made up of many cells, each secreting into the lumen of the balloon. The secretion is carried through the string (duct), where it combines with the secretions of other acini. As all the strings come together, it is eventually carried out through a large duct.

c. Compare a liver lobule to a bicycle wheel. The central vein is in the "hub" of the wheel, and the vessels of the portal triad are arranged around the periphery. The spokes are thin lines of cells (hepatocytes). Some of the spaces between the spokes carry blood in toward the hub; other spaces carry bile out toward the tire. The spokes are the only thing separating the blood channels (sinusoids) from the bile channels (canaliculi). They are made of a single layer of hepatocytes, like a wall one brick thick between streams flowing in opposite directions. If you could stand on top of the wall and look down into the streams, you would notice that the blood is actually a mixture of oxygenated blood from the hepatic artery and deoxygenated blood and nutrients from the hepatic portal vein. All of the blood flows toward the central vein in the hub. On the other side of the wall is the bile. It seems to be coming from the hepatocytes themselves, as they process the molecules in the blood from the other side. The microvilli on their surface enable them to absorb quickly, and then secrete back into the blood sinusoid or bile canaliculus. The bile is flowing, in the opposite direction as the blood, toward the periphery, where it seems to disappear down the bile duct like water down the bathtub drain.

2. Demonstrations

3. Vocabulary Aids

a. The name for the parotid gland translates literally as near the ear (par-otid).

b. A mnemonic device that makes the students giggle but helps them remember the four types of teeth from anterior to posterior (i, c, b, m, [incisors, cuspids (canines), bicuspids (premolars), molars]) is, "I see b. m. (bowel movement)."

c. Wisdom teeth were given their name, because they come in at about the age of 18 - 21 years, when we're supposed to be older and wiser.

d. The phases of swallowing are named for the anatomical location of the area that contains the bolus.

THE BUCCAL PHASE
THE PHARYNGEAL PHASE
THE ESOPHAGEAL PHASE

e. The cardiac portion of the stomach gets its name because it is closest to the heart. The fundus provides "shaker space," because it rarely gets full (except during Thanksgiving dinner).

f. The effects of the enzyme rennin can be seen if you have ever been lucky enough to witness a baby spit-up, the milk appears curdled. Be sure to distinguish this enzyme from the renal enzyme renin involved in blood pressure control.

g. The jejunum and ileum make up most of the small intestine. The duodenum only occupies the first 12 inches (hence, the name).

h. Describe carefully the difference between glycogenolysis and gluconeogenesis. At this point, the students may be familiar enough with the word elements to be able to dissect the words and come up with a meaning.

4. Applications

a. Ask the students if they can recall what cranial nerve provides most of the parasympathetic control of the muscularis layer (vagus).

b. The frenulum helps hold the tongue in place; it works better on some people than on others. Individuals with the condition of ankyloglossia were sometimes referred to as "tongue tied." Correction is made by snipping part of the frenulum to loosen its restriction of the tongue.

c. The enzyme, salivary amylase, initiates carbohydrate digestion in the mouth. Years ago, baby food manufacturers were called to task because of the excess amounts of carbohydrate fillers that were put into jarred baby food in the place of other, more nutritive (and more expensive) substances. The amount of carbohydrates was evident. If a parent fed the baby directly from the jar and then put the unfinished portion in the refrigerator, the next day the food would be completely liquified. The baby's salivary amylase was introduced into the jar with the spoon, and by morning the enzyme activity had done its work.

d. Newborns may suffer from chalasia. Instead of the esophageal sphincter not opening, as with achalasia, this condition is marked by relaxation and dilatation of the sphincter. Its alternate name, "projectile vomiting," does a pretty adequate job of describing the symptoms. The baby usually outgrows the condition by six to eight months of age.

e. Alcohol's effect on gastric secretion and motility is the reason why a glass of wine as an aperitif is recommended for "good digestion."

f. Diets low in protein and high in carbohydrate and fiber have been linked to a decreased chance of colon cancer. This may be because the increased bulk causes food to move through the digestive tract more quickly.

g. Cirrhosis occurs when the liver is damaged beyond its ability to regenerate itself. In this case it "fills in" the damaged area with scar tissue, like a scar that forms on a tree that has been struck by lightening. The scar keeps the tree from dying, but it can never produce limbs, leaves, or fruit. The fibrous tissue in the liver fills in the gap, but it cannot function like a liver.

5. Common Student Misconceptions/Problems

a. Students certainly have a sense of familiarity with the digestive system. However, they tend to think of it as a system that produces waste products from the foods we eat, as opposed to a system that primarily takes in what it needs from the digestive tract, leaving the rest to pass on through. This is a subtle difference, perhaps, but an important distinction that will be necessary when it comes time to talk about the urinary system. They often think of the systems as somehow related. Perhaps if you use the following analogy, it will help them to perceive the difference.

You have gone to the cafeteria for lunch, and as you pass down the line of foods that are being offered, you put onto your tray (the digestive tract) the items that look appetizing. As you sit down to enjoy the meal, you remove the plastic wrap from the dishes, unwrap the butter and spread it on the corn-on-the-cob, open the milk carton and pour the milk into your glass, cut your meat into smaller pieces, all the manipulations that put the food in a condition that will enable you to actually put it in your mouth (digestion and absorption). When you are finished, you have a tray of items that you never ate: the plate, the glass, the silverware, the napkin, the plastic wrapping, the cob and the chicken bones. These items are not on the tray, because you ate them and then spit them out; they are there because they were never eaten in the first place. You pick up your tray and carry it to the disposal window (elimination). For the most part, what we call waste products of the digestive system are, with a few exceptions, undigestible and unabsorbable leftovers from the food with which we started. Remind the students about the difference between "inside" and "outside" the body. As long as the digested materials stay in the digestive tract, they are never inside the body (like the items left on the tray).

b. While students understand about the neural control of the smooth muscle within the digestive tract, it does not usually occur to them that there is neural and hormonal coordination or orchestration of the digestive processes as the food progresses from one area of the tract to the next. They imagine that food is dumped in one end, it works its way through while magic things happen, until finally, there is light at the end of the tunnel (FLUSH!). Explain that the process and progress is coordinated with a series of neural and hormonal activities.

c. Most students are not used to thinking of the rectum and anus as parts of the colon. The lining of the distal portion of the rectum reverts back to stratified squamous epithelium, as was seen at the beginning of the digestive tract. The stratified layer represents an invagination from the outside surface and protects the surface from the abrasion of the feces.

6. Lecture ideas

a. The functional organization of the digestive tract is especially obvious in its structural organization and histology. Point out that, at one level, the general histological "theme" of the digestive system continues from beginning to end. The same four layers can be found whether examining a cross-section through the esophagus or through the rectum. The basic components of the layers (i.e., a mucous membrane, a muscular layer, and an outer, serosal or adventitia layer) are seen repeated in many hollow organs (e.g., a blood vessel, the gall bladder, the urinary bladder, the wall of the heart). At another level, variations of that theme exist from one part of the digestive tract to the next and reflect the six basic digestive system functions.

b. The epithelium changes from stratified squamous to simple columnar rather abruptly at the junction of the esophagus and stomach (sometimes called the "Z" line). When one takes into consideration that the esophagus is 1) an invagination from the external epidermis, and 2) constantly being abraded by food, then it makes sense that it should be covered by many layers of cells that are easily regenerated. The stomach and intestines, on the other hand, must have a single layer of cells, since they do so much work across the surface. Those cells need to contain a considerable amount of "equipment" to perform the tasks required of them, RER, smooth ER, Golgi, mitochondria, secretory vesicles, etc. All that equipment takes up space; hence, the need for simple columnar epithelium (as opposed to squamous or cuboidal).

c. Stress that the gall bladder does not produce bile, but stores and concentrates the bile that is produced by the liver. That is why people can have it removed and still survive. In the case of a cholecystectomy, bile is "stored" in the hepatic and common bile ducts, but obviously cannot be concentrated as before.

d. Many times, instructors will end the discussion of the digestive system having given the students the "low down" on the anatomy and physiology, from the perspective of "this is what the organs do." If discussion is stopped, they never get to find out "what it's done to" and walk away with only a general sense of the process. It might be effective to broaden their perspective by having the students develop a simple menu, nothing too complicated, but it should have an item from each of the main food

groups: carbohydrates, proteins, and lipids (chocolate?). You can throw in a multivitamin for good measure. Have them "walk the meal through" the digestive organs starting with the cephalic phase and ending in the toilet. Encourage them to be creative, BUT CORRECT! This makes a great group project, and can even be done as a "dry lab." You can have the students divide up the parts of the digestive process among the groups or individuals within one group. Each group can contribute to the digestive process until every nutrient has been accounted for. Your job is to be a facilitator of the learning process by making sure that the exercise remains in good taste, is chewed over sufficiently, and is easy to digest.

Answers to End of Chapter Exercises

Level 1: Reviewing Facts and Terms

1. d
2. a
3. d
4. d
5. d
6. b
7. b
8. a
9. c
10. b
11. d
12. d
13. a
14. d
15. d
16. c
17. a

18. (1) ingestion (2) mechanical processing (3) secretion (4) digestion (5) absorption (6) excretion.

19. The folds increase the surface area available for absorption and may permit expansion of the lumen after a large meal.

20. muscosa-epithelial layer that performs chemical digestion and absorption of nutrients; submucosa-connective tissue layer containing lymph and blood vessels and the submucosal nerve plexus; muscularis externa-smooth muscle layer, contains myenteric nerve plexus; serosa-outermost layer, connective tissue that is forms the visceral peritoneum

21. (1) neural mechanisms (2) hormonal mechanisms (3) local mechanisms

22. The serosa or visceral peritoneum is continuous with the parietal peritoneum that lines the inner surfaces of the body wall. The mesenteries are double sheets of peritoneal serous membranes that connect the parietal peritoneum with the visceral peritoneum. The mesenteries provide an access route for the passage of the blood vessels, nerves, and lymphatics to and from the digestive tract. They also stabilize the position of the attached organs, and prevent the intestines from becoming entangled during digestive movements or sudden changes in body positions.

23. (1) sensory analysis of material before swallowing
(2) mechanical processing through the actions of the teeth, tongue, and palatal surfaces
(3) lubrication by mixing with mucus and salivary secretions
(4) limited digestion of carbohydrates and lipids

24. (1) parotid salivary glands - Stensen's duct
(2) sublingual salivary glands - Rivunus' ducts
(3) submandibular salivary glands - Wharton's ducts

25. lubrication of the mouth; moistening and lubrication of materials in the mouth; dissolving chemicals that can stimulate the taste buds and provide sensory information about the material; initiating the digestion of complex carbohydrates before the material is swallowed. Salivary secretions are usually controlled by the ANS. Parasympathetic stimulation accelerates salivary secretion, while it is believed that sympathetic innervation promotes the secretion of small amounts of very thick saliva.

26. (1) incisors - clipping or cutting; (2) cuspids - tearing or slashing; (3) bicuspids - crushing, mashing, grinding; (4) molars - crushing and grinding

27. The pharyngeal constrictors push the bolus toward the esophagus. The palatopharyngeus and stylopharyngeus elevate the larynx. The palatal muscles raise the soft palate and adjacent portions of the pharyngeal wall.

28. (1) buccal phase; (2) pharyngeal phase; (3) esophageal phase. Swallowing is controlled by the swallowing center of the medulla oblongata via the trigeminal and glossopharyngeal nerves. The motor commands originating at the swallowing center are distributed by cranial nerves V, IX, X and XII. Along the esophagus, primary peristaltic contractions are coordinated by afferent and efferent fibers within the glossopharyngeal and vagus nerves, but secondary peristaltic contractions occur in the absence of CNS instructions.

29. The gastric glands are dominated by two types of secretory cells: parietal and chief cells. Parietal cells secrete intrinsic factors and hydrochloric acid. Intrinsic factor facilitates the absorption of vitamin B_{12} across the intestinal lining. The low pH of gastric juice kills most of the microorganisms ingested with food. The acid helps break down plant cell walls and the connective tissues in meat. The acid environment is essential for the activation and function of pepsin, a protein-digesting enzyme. Chief cells secrete pepsinogen, an inactive proenzyme that is converted by the acid in the lumen to its active form, pepsin. The pyloric glands consist of G cells, which produce gastrin, and D cells, which release somatostatin, a hormone that inhibits gastrin release. Gastrin stimulates the secretion of both parietal and chief cells and contractions of the gastric wall that mix and stir the gastric contents.

30. (1) duodenum (2) jejunum (3) ileum

31. The pancreas provides digestive enzymes as well as buffers that assist in the neutralization of acid chyme. The liver and gallbladder provide bile, a solution that contains additional buffers and bile salts that facilitate the digestion and absorption of lipids. The liver is responsible for metabolic regulation, hematological regulation and bile production. It is the primary organ involved with regulating the composition of the circulating blood.

32. Enterocrinin - stimulates the submucosal glands of the duodenum. Secretin – stimulates the pancreas and liver to increase the secretion of water and buffers. Cholecystokinin (CCK) - causes an increase in the release of pancreatic secretions and bile into the duodenum. It also inhibits gastric activity and appears to have CNS effects that reduce the sensation of hunger. Gastric inhibitory peptide (GIP) - known as glucose-dependent insulinotropic peptide, stimulates insulin release at pancreatic islets and the activity of the duodenal-submucosal glands. Vasoactive intestinal peptide (VIP) - stimulates the secretion of intestinal glands, dilates regional capillaries, and inhibits acid production in the stomach. Gastrin - secreted by G cells in the duodenum when they are exposed to large quantities of incompletely digested proteins. Small quantities: motilin, which stimulates intestinal contractions, villikinin, which promotes movement of villi and associated lymph flow, and somatostatin, which inhibits gastric secretion.

33. (1) resorption of water and compaction of intestinal contents into feces (2) absorption of important vitamins liberated by bacterial action (3) storage of fecal material prior to defecation

34. (1) Stretch receptors in the rectal walls order a series of peristaltic contractions in the colon and rectum, moving feces toward the anus (2) The sacral parasympathetic system, also activated by the stretch receptors, stimulates peristalsis via motor commands distributed by the pelvic nerves.

35. (1) The rate of epithelial stem cell division declines; (2) Smooth muscle tone decreases; (3) The effects of cumulative damage become apparent; (4) Cancer rates increase; (5) Changes in other systems have direct or indirect effects on; the digestive system

Level 2: Reviewing Concepts

36. d
37. c
38. d
39. d
40. d
41. a

42. incisors

43. Peristalsis consists of waves of muscular contractions that move along the length of the digestive tract. During a peristaltic movement, the circular muscles contract behind the digestive contents. Longitudinal muscles contract next, shortening adjacent segments. A wave of contraction in the circular muscles then forces the materials in the desired direction. Segmentation movements churn and fragment the digestive materials, mixing the contents with intestinal secretions. Because they do not follow a set pattern, segmentation movements do not produce directional movement of materials along the tract.

44. The stomach performs four major functions: the bulk storage of ingested food; the mechanical breakdown of ingested food; the disruption of chemical bonds through the actions of acids and enzymes; the production of intrinsic factor.

45. (1) The cephalic phase begins with the sight or thought of food. Directed by the CNS, this phase prepares the stomach to receive food. (2) The gastric phase begins with the arrival of food in the stomach. The gastric phase is initiated by: distension of the stomach, an increase in the pH of the gastric contents, and the presence of undigested materials in the stomach. (3) The intestinal phase begins when chyme starts to enter the small intestine. This phase controls the rate of gastric emptying and ensures that the secretory, digestive, and absorptive functions of the small intestine can proceed at reasonable efficiency.

46. Aspirin is acidic, and acids aggravate stomach ulcers. Also, aspirin promotes bleeding, interfering with the healing of ulcers.

47. After a heavy meal, the blood pH increases because bicarbonate ions pass from the parietal cells of the stomach into the extracellular fluid, causing the pH of the extracellular fluid to rise. As the extracellular fluid exchanges ions with the blood, the blood pH also increases.

Level 3: Critical Thinking/Application

48. If the gallstone is small enough, it can pass through the common bile duct and block the pancreatic duct. Enzymes from the pancreas will not be able to reach the small intestine, and as they accumulate, they will irritate the duct and ultimately the exocrine pancreas, producing pancreatitis.

49. The small intestine, especially the jejunum and ileum, are probably involved. Regional inflammation is the cause of Barb's pain. The inflamed tissue will not absorb nutrients. This accounts for her weight loss. Among the nutrients that are not absorbed are iron and vitamin B_{12}, which are necessary for formation of hemoglobin and red blood cells. This accounts for the anemia.

50. You would expect to observe pain as the intestinal contents continued to accumulate and stretch the intestinal wall. There would be abdominal distention in the region proximal to the obstruction. Since material cannot exit the intestine, vomiting would occur as the intestinal contents increased, causing increased pressure and irritation of the intestine. The vomitus would contain bile, since little of the bile would be absorbed by the blocked intestine. There would be no feces or intestinal gas produced by the intestine distal to the blockage. Since the blockage occurs in the region of the jejunum, some absorption of nutrients would take place, but not as much as normal due to the distention and the irritation of the intestine. This would lead to various symptoms of malnutrition.

❑ Media Lab Instructor Notes

Web addresses often change. To avoid dead links, we are listing the keywords in parentheses next the to Web Explorations. Simply go to the Companion Website (http://www.prenhall.com/martini), select the Fifth Edition of Fundamentals of Anatomy and Physiology and search using the key word to locate the current address.

Animations (Website)

- Figure 24-2—Animation with roll-over labels. Structure of the digestive tract; suitable for lecture demonstration of GI tract anatomy or self-study.
- Figure 24-4—Animation in play / next format. The regulation of digestive activities; suitable for lecture demonstration of feedback mechanisms in digestion.
- Figure 24-22—Animation in play / next format. The activities of major digestive tract hormones; suitable for lecture demonstration of digestive hormones or self-study tool after presentation.

Animations (CD-ROM)

- Rotating 3-dimensional image of digestive system corresponding to Figure 24-1 Components of the digestive system.

Web Explorations (Overview)
Web Exploration 1 (**GI QUIZ**)

- *Goal*—review, knowledge transfer
- *Description of page*—Anatomically correct on-line cat dissection quiz
- *Expectations of student behavior*—study text, compare images with quiz, re-do quiz until correct
- *Instructor's role*—assist in interpretation of image; help navigate to second quiz
- *Special notes or further uses of exploration*—links to quizzes on urogenital system and respiratory system

Web Exploration 2 (**HEPATITIS**)

- *Goal*—current events, critical thinking
- *Description of page*—Dr. Everett Koop page on Hepatitis C epidemiology
- *Expectations of student behavior*—read article, fill out table comparing hepatitis viruses
- *Instructor's role*—explain hepatitis, discuss liver functioning, assist in table formation
- *Special notes or further uses of exploration*—site links to explanation of viruses, liver discussion

Additional Web Explorations
Should the two explorations found in the text not answer your needs, a third exploration is provided below. Your students do not have direct access to this exploration. You must provide them the address and information in the following paragraph.

Web Exploration 3
Estimated time for completion = 10 minutes

The stomach is the first organ of the digestive tract that most people think of when they discuss this system. Although it seems fairly straightforward, quite a lot is known about the stomach. A good summary of the anatomy of the **STOMACH** can be found at this site (http://www.ee.ualberta.ca/~mintchev/stomach.html). Read the article, and compare the illustrations to those found in the text. Draw a diagram of the anatomy of the stomach top serve as a study guide as you continue your studies into digestion and metabolism.

Web Exploration 3 (**STOMACH**)

- *Goal*—review, organize information
- *Description of page*—University of Alberta Electrical Engineering page leading to electrical impulses of stomach
- *Expectations of student behavior*—read, study the diagram, reproduce the image
- *Instructor's role*—discuss gastric anatomy and function; assist in student drawing
- *Special notes or further uses of exploration*—link at bottom of page leads to difficult electrical impulses of stomach information (beyond scope of text)

Topic Outline				A/V Resources				
Objectives	**Chapter 24** **The Digestive System** (page 1 of 6)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	I. Introduction		5a					
	II. An Overview of the Structure and Function of the Digestive Tract	24-1		●	●			●
1b	A. Histological Organization of the Digestive Tract	24-2	6a	●	●	●		●
1a	1. The Mucosa	24-2	6b	●	●			●
1c	2. The Submucosa	24-2		●	●			●
	3. The Muscularis Externa		4a					
	4. The Serosa	24-2		●	●			
1d	B. The Movement of Digestive Materials							
	1. Peristalsis	24-3		●	●			
	2. Segmentation							
1e	C. The Control of Digestive Function	24-4	5b	●	●	●		
	1. Neural Mechanisms							
	2. Hormonal Mechanisms							

Topic Outline				A/V Resources				
Objectives	**Chapter 24** **The Digestive System** (page 2 of 6)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	3. Local Mechanisms							
	D. The Peritoneum							
	1. Mesenteries	24-2,5		●	●	●		
1f	**III. The Oral Cavity**	24-6		●	●			
	A. The Tongue	24-6	4b	●	●			
	B. Salivary Glands	24-6a,7	3a	●	●			
	1. Saliva		4c					
	2. Control of Salivary Section							
	C. The Teeth	24-8a			●			
	1. Types of Teeth	24-8b	3b		●			
	2. Dental Succession	24-9	3c		●			
	3. Mastication							
1f	**IV. The Pharynx**							
1f	**V. The Esphagus**	24-10		●	●			

Objectives	TOPIC OUTLINE **Chapter 24** **The Digestive System** (page 3 of 6)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	A. Histology of the Esophagus	24-2,10		●	●			
	B. Swallowing	24-11	3d, 4d	●	●			
1g	**VI. The Stomach**							
	A. Anatomy of the Stomach	24-12	3e	●	●			●
	1. Musculature of the Stomach	24-12b		●	●			
	2. Histology of the Stomach	24-13	3f	●	●			●
	B. Regulation of Gastric Activity	24-15		●	●			
1k	1. The Cephalic Phase	24-15a		●	●			
	2. The Gastric Phase	24-15b		●	●			
	3. The Intestinal Phase	24-15c	4ef	●	●			
	C. Digestion and Absorption in the Stomach							
	VII. The Small Intestine and Associated Glandular Organs							
1h	A. The Small Intestine	1-7, 24-5,16a	3g	●	●			
	1. Histology of the Small Intestine	24-17		●	●			●

Objectives	Topic Outline: **Chapter 24 The Digestive System** (page 4 of 6)	Figures	Strategies	A/V Resources: Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	2. Intestinal Secretions							
	B. Intestinal Movements							
1j	C. The Pancreas	24-18a,21b		●	●			
	1. Histological Organization	24-18bc		●	●			
	2. Physiology of the Pancreas							
1j	D. The Liver							
	1. Anatomy of the Liver	21-27,35 24-19		●	●			●
	2. Histological Organization of the Liver	24-20	1c	●	●			
	3. The Bile Duct System	24-21		●	●			
	4. The Physiology of the Liver		3h, 4g					
1e	E. The Gallbladder	24-21		●	●			
	1. Physiology of the Gallbladder		6c					
1k	F. The Coordination of Secretion and Absorption	24-22		●	●	●		
	1. Intestinal Hormones							

Objectives	TOPIC OUTLINE **Chapter 24** **The Digestive System** (page 5 of 6)	Figures	Strategies	A/V RESOURCES: Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	2. Intestinal Absorption							
	VIII. The Large Intestine	24-16a,23		●	●			
11	A. The Cecum	24-23ab		●	●			
	B. The Colon	24-23ac		●	●			
	C. The Rectum	24-23ac	5c	●	●			
	D. Histology of the Large Intestine	24-24		●	●			
	E. Physiology of the Large Intestine							
	1. Absorption in the Large Intestine							
	2. Movements of the Large Intestine	24-25		●	●			
	IX. Digestion and Absorption		6d					
	A. The Processing and Absorption of Nutrients	24-26		●	●			
1	B. Carbohydrate Digestion and Absorption							
	1. Salivary and Pancreatic Enzymes	24-26a		●	●			
	2. Brush Border Enzymes							

Topic Outline				A/V Resources				
Objectives	**Chapter 24** **The Digestive System** (page 6 of 6)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	3. Absorption of Monosaccharides	3-9		●	●			
1m	C. Lipid Digestion and Absorption	2-15, 24-26b		●	●			
1m	D. Protein Digestion and Absorption	24-26c		●	●			
	1. Absorption of Amino Acids							
1n	E. Water Absorption	24-27		●	●			
1n	F. Ion Absorption	24-28		●	●			
1n	G. Vitamin Absorption	24-28		●	●			
	X. Aging and the Digestive System							
	XI. Integration with Other Systems	24-29			●			

CHAPTER 25

Metabolism and Energetics

Introduction

An interesting application of the material in this chapter is non-insulin dependent diabetes (NIDDM). Several new approaches to this disease are relevant. In a recent article (*Scientific American Science and Medicine,* July/August, 1994) Hales discusses the role of fetal nutrition in this disease. He presents data that implies that prenatal nutrient deprivation followed but adult nutritional excess correlates strongly with NIDDM. The same phenomenon has been reproduced in animal models. Aspects of carbohydrate, lipid and protein metabolism may play a role. The high incidence of this problem in certain ethnic groups has led to the "Thrifty Gene Hypothesis." One of the best studied groups in this regard are the Pima Indian of Arizona. Among this group, up to 85% of the population shows symptoms of NIDDM. The hypothesis suggests that this may be due to a particular genotype that evolved to help spare glucose utilization in a difficult environment. This gene now makes it difficult to utilize fat when on a "normal American" diet. This issue is discussed in detail in an excellent book by Marc Lappé (*Evolutionary Medicine*, Sierra Book Club, 1994).

Instructional Goals/Learning Objectives

1. To provide an appreciation for the metabolic interactions between different tissues, and to show how the interactions preserve homeostasis.

   a. *Define metabolism and explain why cells need to synthesize new organic components.*
   b. *Describe the basic steps in glycolysis, TCA cycle, and the electron transport system.*
   c. *Summarize the energy yield of glycolysis and cellular respiration.*
   d. *Describe the pathways involved in lipid metabolism and the mechanisms necessary for lipid transport and distribution.*
   e. *Explain how proteins are metabolized and broken down to provide energy.*
   f. *Describe nucleic acid metabolism and synthesis.*

2. To emphasize the role of hormones in adjusting the metabolic operations within specific tissues, and to reinforce the material presented on the endocrine system (Chapter 18).

   a. *Differentiate between the absorptive and postabsorptive metabolic states and summarize the characteristics of each.*
   b. *Explain what constitutes a balanced diet, and why it is important.*
   c. *Define metabolic rate and discuss the factors involved in determining one's BMR.*
   d. *Discuss the homeostatic mechanisms that maintain a constant body temperature.*

3. To familiarize students with the basic rationale of dietary planning and to get them to question the wisdom of a junk-food diet.

❑ Teaching Strategies

1. Analogies

a. The two substrate-level ATP molecules gained from glycolysis are "gravy." They just happen to be a little bonus gained during the process of splitting the 6-carbon chain into two 3-carbon chains. If you're on your way to the bank to cash your check (glucose), finding a couple of dollars (ATPs) on the sidewalk outside the bank would be a serendipitous event. Of course, most of the money is in the bank (mitochondria), but that doesn't mean you won't enjoy spending the money you found outside (cytoplasm). As far as merchants are concerned, they don't care whether you got the money on the street (substrate level) or in the bank.

b. As an analogy for electron transport, suppose you live in a small village, and the people of the village get their water from a cistern located in the center of town. The village is on top of a mountain, and down in the valley, there is a lake that is used to fill the cistern when it runs dry. Since there is no aquifer, the water must be carried up the mountain in buckets. The trouble is, you're so thirsty by the time you get to the top, you end up drinking half the water right then. Certainly there must be a more energy efficient way to accomplish the task. Suppose all the people in the town stand in a single line (there aren't enough people to make two lines) that extends from the lake, up the mountain, to the cistern in the center of town (the cytochrome chain). Each person holds a bucket (electron acceptors). The person at the bottom of the mountain dips his bucket into the lake, fills it with water (the hydrogens), and then pours that water into the bucket of the person uphill from him, who in turn pours the water in the bucket of the person uphill from her, who in turn pours the water in the bucket uphill from him, etc. The person at the bottom of the mountain keeps scooping the water out of the lake; the person at the end of the line dumps the water into the cistern. So, the people were able to transfer the water up the mountain to a higher level (of energy), and they did it in small, incremental steps.

c. The absorptive state is equivalent to going to the grocery store to buy food in order to fill up the refrigerator and cupboards. While the postabsorptive state represents the times between the shopping trips when you have to rely on what's in the house for meals.

2. Demonstrations

a. Have the students participate in the following critical thinking exercise. Divide the class into groups of about six to eight students. Assign each group a descriptive situation with which they can identify. For example, 1) having to stand outside on a cold day, waiting for a bus that is already 30 minutes late, 2) having to stand outside on a hot day, waiting for a bus that is already 30 minutes late, or 3) going out with your friends and consuming nothing but beer for your dinner. Instruct the students that the exercise is going to be "played" in four parts:

1) A short writing session for recording observations about their topic. As a group, they will spend 10 or 15 minutes writing down all the subjective observations

that they can think of. For the first example, they might list observations such as shivering, stamping their feet, huddling down into their coat, wishing they had worn a hat, developing a feeling of numbness in their fingers and toes, etc. You should then collect their results.

2) A background/information gathering session. As the resident authority, you will lecture on and discuss the topics of bioenergetics.

3) A second writing session for recording physiological explanations of all the subjective observations. Hand back to each group their original list. Armed with their notes (and textbook), instruct them to record physiological explanations for all of their subjective observations; i.e., give the reason for what they felt or did.

4) Reporting of the results. A previously agreed upon spokesperson will report to the rest of the class the results of their collective observations and analyses.

The exercise is effective, because 1) it requires the students to think about an everyday situation in terms of personal observations, 2) it gets them involved in a limited amount of writing, 3) they must analyze and summarize information to determine its applicability, and 4) it helps to illustrate that physiology happens "where they live."

3. Vocabulary Aids

a. Pull the word "glycolysis" apart to show its meaning, "Glyco" "lysis": the cutting of glucose.

4. Applications

a. In the absence of oxygen, pyruvate will be broken down into lactic acid, which results in sore muscles when we over exert (especially if we are out of condition).

b. Phenylketonuria (PKU) is a genetic disease that causes irreversible damage to the CNS, but the effects can be easily avoided if PKU children are kept on diets that restrict their phenylalanine intake. Most states required a blood test to be performed on all newborns designed to detect the condition. The children usually "outgrow" the problem as alternate metabolic pathways develop later on in life. Check out the label on the next diet soda you drink, and you will see a warning addressed to people with PKU. Aspartame (Nutrisweet^{TM}) has a phenylalanine component.

c. People suffering from uncontrolled diabetes mellitus may have breath that smells like acetone, or fingernail polish remover. Since glucose from carbohydrate and fat breakdown is not getting into the cells, the cells perceive themselves as "starving," and protein catabolism kicks in. The odor is a result of increased levels of ketones in the blood, which can lead to ketosis, ketoacidosis, and even death.

5. Common Student Misconceptions/Problems

a. Most students are not aware of the difference between minerals and vitamins; they just think of them collectively as the stuff you get in vitamin pills. Stress that minerals are inorganic substances found in the earth, like salt, zinc, and iron. We can't make our own minerals, which is why we must get them from a dietary source. Point out that vitamins are organic substances, and as such we have limited ability to produce trace amounts of certain vitamins. We still must rely on dietary sources to provide adequate amounts. Indicate that vitamins are usually named with a letter (A, B_1, B_{12}, C. D, E, K, etc.).

6. Lecture ideas

a. Sometimes it helps to begin the discussion of a complex topic by first describing the "big picture." It gives the students a sense of where they're headed, and it helps them to recognize that place once they get there. In other words, put yourself in their place and ask the question that they will be asking after your elaborate but artistic description of glycolysis and the TCA cycle: "So?" Perhaps one way of demonstrating the significance of cellular metabolism (that is, the relevancy to their lives) is to ask the students, to: "Imagine going into the grocery store, and instead of seeing the large signs overhead directing you to 'PRODUCE' or 'BAKERY' or 'CANNED FRUITS,' all you see are signs that say, 'CARBOHYDRATES,' 'LIPIDS,' 'PROTEINS,' and 'NUCLEIC ACIDS.' Would you leave the store figuring it was some weird health food co-op, or would you be able to purchase all the items you usually purchase? What kinds of things do you suppose would be in your cart? Hopefully, the students will come to the conclusion that there IS no difference, and they will provide a list of normal food items. Write these items on the board until you have a long list that includes the four major categories of nutrients. Bring this point to their attention: "As we look at the list, no matter what shape the packages are in when we bring them home from the store, no matter what we do to them prior to eating the food, no matter how we look at it, all of this food can be divided up into four basic categories: carbohydrates (which includes starches and sugars), lipids, proteins, and nucleic acids. In the previous chapter, we learned how we get the food ingested, digested, and absorbed. We even know the blood flow pattern from the digestive organs through the hepatic portal system and back into the inferior vena cava from Chapter 21. But, what happens next? We have these nutrients in the blood. They are traveling around to be delivered to the cells. Once the nutrients diffuse or are transported out of the blood into the interstitial fluid around the cells, and then into the cells, what happens next?

Examine Figures 25-1 and 25-2 very carefully with the students. They may seem simplified, but they represent the big picture, tell-me-where-we're-headed, view that the students need to see. As you discuss carbohydrate metabolism, the tendency will be to pay such close attention to the details of what you're describing, that the students will lose sight of the trees let alone the forest. If necessary, bring them back to these diagrams from time to time in order to give them the opportunity to put everything in context.

b. Write the overall reaction of carbohydrate metabolism on the board:

$$C_6H_{12}O_6 \ + \ 6O_2 \quad \Rightarrow \quad 6CO_2 + \ 6H_2O$$

glucose oxygen carbon dioxide water

Many of the students will be familiar with this reaction, ask them if they believe that the "point" of this reaction is to get carbon dioxide and water. That is, if glucose is the nutrient that our cells need, do the cells break the glucose down just so they can end up with carbon dioxide and water? Of course not. What the cells want is energy. They need the energy to run the machinery in the factory. That energy is packaged in molecules called ATP. Think of the glucose as the precious metal, the gold, that exists in raw form. The cells have to convert the gold to ingots,which then can be used to develop the currency system. If the glucose is the raw gold, the ATP is the gold ingot, and the high-energy bonds of the ATP represent the money that the cell can spend.

Students like to memorize the number of ATP molecules that result from carbohydrate metabolism, because that is the way they were taught, but try to show them that is not the point. It is the process of getting those ATPs that needs to be examined. As a very basic observation, point out that if you compare the left side of the reaction with the right side, the main difference appears to be the removal of the hydrogens from the glucose (leaving carbons and oxygens for the formation of the carbon dioxide) and the placement of those hydrogens with the oxygens to result in water. If hydrogen ions are going to be moved from place to place, there has to be a carrier to move them. When a chemical reaction results in the removal of H^+ from a molecule (the loss of an electron), the molecule is said to be oxidized. But we can't just have hydrogen ions floating around, they're real trouble makers, if they are left unattended. That means they have to be attached to another molecule, a hydrogen carrier. When a molecule takes on a hydrogen (the gain of an electron), the molecule is said to be reduced. So, in order to move those hydrogens from the glucose, we need to go through a series of oxidation/reduction steps. In the process, we will create energy to package in ATP, but we will need to rely on important hydrogen carrier molecules, such as NAD^+ and FAD^+.

c. Point out that when we say, "Electron Transport System," the electrons that we're talking about come from the hydrogens mentioned above. Thus, the ETS is nothing more than the above mentioned series of oxidation/reduction reactions, occurring around the cytochromes.

d. Lipids are made of all the same molecules as glucose, only put together in a different combination. It stands to reason that if we had some way of reorganizing the carbon, hydrogen, and oxygen molecules to form pyruvate, we could just funnel the pyruvate into the mitochondrion, and BINGO!, out would come ATP (and who knows how many substrate level ATPs we might find along the way!). Since lipids are larger

molecules than glucose, their catabolism yields more pyruvates, and therefore, more ATPs. That is why lipids are referred to as "high-energy" molecules. It is also why fats have more calories per unit weight (9 kcal/gm) than sugars (4 kcal/gm). The same logic applies to proteins. If proteins are made of all the same molecules as glucose, only put together in a different combination, then it stands to reason that if we had some way of reorganizing the carbon, hydrogen, and oxygen molecules to form pyruvate, we could take advantage of the TCA cycle.

e. Research and information about diet and nutrition are constantly being updated. The food pyramid of today is considerably different from the recommended basic food groups a generation ago. If you have access to an old chart of the basic food groups. it might be interesting for the students to see how ideas have changed (especially with regards to the amounts of meats and fats).

Answers to End of Chapter Exercises

Level 1: Reviewing Facts and Terms

1. d
2. c
3. a
4. c
5. a
6. d
7. c
8. c
9. a
10. a
11. d
12. c
13. d
14. b
15. a
16. b
17. c
18. a
19. b
20. c
21. a
22. d
23. b

24. Metabolism is all of the chemical reactions occurring in the cells of the body. Anabolism is those chemical reactions resulting in the synthesis of complex molecules from simpler reactants. Anabolic products are used for maintenance/repair, growth, and secretion. Catabolism is the breakdown of complex molecules into their building block molecules, resulting in the release of energy for the synthesis of ATP and related molecules.

25. $C_6H_{12}O_6 + 6\ O_2 \Rightarrow 6\ CO_2 + 6\ H_2O$

26. Lipoproteins are lipid-protein complexes that contain large insoluble glycerides and cholesterol, with a superficial coating of phospholipids and proteins. The major groups are chylomicrons which are 95% triglyceride, are the largest lipoproteins, and carry absorbed lipids from the intestinal tract to the circulation. Very low-density lipoproteins (VLDLs) which consist of triglyceride, phospholipid, and cholesterol, and function in transporting triglycerides to peripheral tissues. Intermediate-density lipoproteins (IDLs) which are intermediate in size and composition between VLDLs and LDLs. Low-density lipoproteins (LDLs) which are mostly cholesterol, and function in delivering cholesterol to peripheral tissues. Sometimes this cholesterol gets deposited in arteries, hence the designation of LDLs as "bad cholesterol." High-density lipoproteins (HDLs) which are equal parts protein and lipid (cholesterol and phospholipids). HDLs function in transporting excess cholesterol back to the liver for storage or excretion in the bile, and are known as "good cholesterol."

27. Most vitamins and all minerals must be provided in the diet because the body cannot synthesize these nutrients.

28. carbohydrates - 4.18 C/g; lipids - 9.46 C/g; proteins - 4.32 C/g

29. The BMR is the minimum, resting energy expenditures of an awake, alert person.

30. (1) radiation (heat loss as infrared waves)
(2) conduction (heat loss to surfaces in physical contact
(3) convection (heat loss to the air)
(4) evaporation (heat loss with water being vaporized on the skin)

31. abnormalities of thermoregulation, such as heat exhaustion or heat stroke; clinical problems that restrict circulation; conditions that impair sweat gland activity; resetting of hypothalamic thermostat by circulating pyrogens

Level 2: Reviewing Concepts

32. d
33. b

34. Glycolysis results in the breakdown of glucose to pyruvic acid through a series of enzymatic steps. 4 ATP and 2 NADH are also produced. Glycolysis requires: glucose, specific cytoplasmic enzymes, ATP and ADP, inorganic phosphates, NAD or nicotinamide adenine dinucleotide, a coenzyme.

35. The TCA reaction sequence is a cycle because the four-carbon starting compound (oxaloacetic acid) is regenerated at the end. Acetyl-CoA and oxaloacetic acid enter the cycle, and CO_2, NADH, ATP, $FADH_2$, and oxaloacetic acid leave the cycle.

36. Oxidative phosphorylation is the generation of ATP within mitochondria, through a reaction sequence that requires coenzymes and consumes oxygen. The electron transport system consists of a sequence of metalloproteins called cytochromes, which pass electrons (from H atoms) along in small steps, gradually releasing energy for the formation of ATP, and producing water as a byproduct.

37. A triglyceride is hydrolysed, yielding glycerol and fatty acids. Glycerol is converted to pyruvic acid, and enters the TCA cycle. Fatty acids are broken into two-carbon fragments by beta-oxidation, a process that occurs inside the mitochondria. The two-carbon compounds then enter the TCA cycle.

38. RNA is broken into its building blocks. The nucleotides are either recycled into new nucleic acids or catabolized to sugars (which enter glycolysis) and nitrogenous bases. The pyrimidine bases are converted into acetyl-CoA for the TCA cycle, and the purines are excreted.

39. The primary hormone of the absorptive state is insulin, which functions in preventing a large surge in blood glucose following a meal. Insulin causes the liver to remove glucose from the hepatic portal circulation. During the postabsorptive state, blood glucose begins to decline, triggering the liver to release glucose via glycogenolysis and gluconeogenesis.

40. Liver cells can break down or synthesize most carbohydrates, lipids, and amino acids. The liver has an extensive blood supply, and thus can easily monitor blood composition of these nutrients and regulate accordingly. The liver also stores energy in the form of glycogen.

41. The food pyramid indicates how much of each food group one should consume per day, to ensure adequate intake of nutrients and calories. The placement of fats, oils, and sugars at the top of the food pyramid indicates that such foods are to be consumed very

sparingly, whereas carbohydrates, represented at the bottom of the pyramid as the bread, cereal, etc. group, is to be consumed in largest relative quantities.

42. The brain contains the "thermostat" of the body, a region known as the hypothalamus. The hypothalamus regulates the ANS control of such mechanisms as sweating and shivering-thermogenesis, via negative feedback homeostatic mechanisms.

43. These terms refer to the HDL and LDL, lipoproteins in the blood that transport cholesterol. HDL ("good cholesterol") transports excess cholesterol to the liver for storage or breakdown, whereas LDL ("bad cholesterol") transports cholesterol to peripheral tissues, which unfortunately may include the arteries. Buildup of cholesterol in the arteries is linked to cardiovascular disease.

Level 3: Critical Thinking/Application

44. Mary's AVR = 10 breaths/min X (300 ml/breath - 150 ml/breath).
AVR = 10 breaths/min X 150 ml/breath = 1500 ml/min
1500 ml/min X 1L/1000 ml = 1.5 L/min
Daily gas consumption = 1.5 L/min X 60 min/hr X 24 hr/day = 2160 L/day
Daily oxygen consumption = 2160 L air/day X 0.18 O_2 = 388.8 L O_2/day
BMR = 388.8 L O_2/day X 4.825 kcal/L O_2 consumed = 1875 kcal (Calories)/day

45. During starvation, the body must use fat and protein reserves to supply the energy necessary to sustain life. Some of the protein that is metabolized for energy is the gamma globulin fraction of the blood, which is mostly composed of antibodies. This loss of antibodies coupled with a lack of amino acids to synthesize new ones, as well as protective molecules like interferon and complement proteins, renders an individual more susceptible to contracting a disease and less likely to recover from it.

46. The response to anorexia is the same as in starvation. In order to supply needed energy, the body utilizes reserves of fat and protein. Once the heart has exhausted its available fat reserves, it begins to break down contractile fibers to use the amino acids from the protein as an energy source. This ultimately leads to a decrease in the size of the heart and a decrease in the force of cardiac contraction. The weakened heart cannot contract as quickly and this results in bradycardia. The combination of bradycardia and decreased force of contraction contribute to the hypotension. Ultimately, the heart will become such an inefficient pump that it will not be able to serve the needs of the body's tissues and death will occur as the result of heart failure.

47. The drug colestipol would lead to a decrease in the plasma levels of cholesterol. Bile salts are necessary for the absorption of fats. If the bile salts cannot be absorbed, this will decrease the amount of fat absorption, namely cholesterol and triglycerides. This would lead to a decrease in cholesterol from a dietary source as well as a decrease in fatty acids that could be used to synthesize new cholesterol. In addition, the body will have to replace the bile salts that are being lost with the feces. Since bile salts are formed from cholesterol, this will also contribute to a decline in cholesterol levels.

❑ Media Lab Instructor Notes

Web addresses often change. To avoid dead links, we are listing the keywords in parentheses next the to Web Explorations. Simply go to the Companion Website (http://www.prenhall.com/martini), select the Fifth Edition of Fundamentals of Anatomy and Physiology and search using the key word to locate the current address.

Animations (Website)

- Figure 25-4—Animation in play / next format. Glycolysis; suitable for lecture demonstration of steps in glycolysis or self-study.
- Figure 25-5—Animation in play / next format. The TCA cycle; suitable for lecture demonstration of carbohydrate metabolism or self-study after presentation.
- Figure 25-6—Animation in play / next format. Oxidative phosphorylation; suitable for lecture demonstration of mitochondrial processes or self-study tool after presentation.

Web Explorations (Overview)

Web Exploration 1 **(TCA)**
- *Goal*—review, practice
- *Description of page*—University of Virginia course page on Krebs; static cycle with animation in lower right corner
- *Expectations of student behavior*—study pages, duplicating cycle
- *Instructor's role*—assist in interpretation of cycle, help move from one page to next and back
- *Special notes or further uses of exploration*—link to Kent state is better description, but inaccessible directly

Web Exploration 2 **(BMR)**

- *Goal*—critical thinking, information application
- *Description of page*—Global health and fitness free BMR calculator, links to other pages inside Global health and fitness
- *Expectations of student behavior*—read short introduction, calculate personal BMR, experiment with variables, writing results and concluding what effect each variable has on BMR
- *Instructor's role*—discuss BMR calculations, assist in scientific method as experiments are designed and results recorded
- *Special notes or further uses of exploration*—links to Global Health (commercial site); questionable information source

Additional Web Explorations
Should the two explorations found in the text not answer your needs, a third exploration is provided below. Your students do not have direct access to this exploration. You must provide them the address and information in the following paragraph.

Web Exploration 3
Estimated time for completion = 10 minutes

Cholesterol metabolism is discussed in your text and in the health box entitled Dietary fats and Cholesterol. To broaden your understanding of **CHOLESTEROL METABOLISM**, visit this site (http://www.nobel.se/laureates/medicine-1985-press.html). Here you can read a discussion of cholesterol metabolism prepared by Michael S. Brown and Joseph L. Goldstein, Nobel prize winners in 1985 for their work with cholesterol. As you read this, prepare an outline of the steps involved in cholesterol metabolism. Include a comparison of HDL, LDL and VLDL in your chart.

Web Exploration 3 (**CHOLESTEROL METABOLISM**)

- *Goal*—review, add to information base
- *Description of page*—Press release 1985 Nobel Prize in Physiology or Medicine
- *Expectations of student behavior*—read, prepare outline
- *Instructor's role*—introduce cholesterol metabolism, assist in interpreting diagrams
- *Special notes or further uses of exploration*—few external links; relatively easy reading

TOPIC OUTLINE				A/V RESOURCES				
Objectives	**Chapter 25** **Metabolism and Energetics** (page 1 of 4)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	I. Introduction		6a					
1a	**II. An Overview of Metabolism**	25-1,2,3		●	●			●
	III. Carbohydrate Metabolism		6b					
1b	A. Glycolysis	25-4	1a, 3a, 4a	●	●	●		
1b	B. Mitochondrial ATP Production							
	1. The TCA Cycle	25-5		●	●	●		
	2. Oxidative Phosphorylation and the ETS	25-6	1b, 6c	●	●	●		
1c	C. Energy Yield of Glycolysis and Cellular Respiration	25-7		●	●			
	D. Other Catabolic Pathways							
	E. Gluconeogenesis	25-8		●	●			
1d	**IV. Lipid Metabolism**		6d					
	A. Lipid Catabolism							
	1. Beta-Oxidation	25-9		●	●			
	2. Lipids and Energy Production							

Topic Outline				A/V Resources				
Objectives	**Chapter 25** **Metabolism and Energetics** (page 2 of 4)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	B. Lipid Synthesis	25-10		●	●			
	C. Lipid Transport and Distribution	25-11		●	●			
1e	**V. Protein Metabolism**							
	A. Amino Acid Catabolism							
	1. Transamination	25-12a	4b	●	●			
	2. Deamination	25-12bc		●	●			
	3. Proteins and ATP Production		4c					
	B. Protein Synthesis	3-24,25, 25-13		●	●			
1f	**VI. Nucleic Acid Metabolism**							
	A. RNA Catabolism							
	B. Nucleic Acid Synthesis	25-14		●	●			
	VII. Metabolic Interactions							
2a	A. The Absorptive State	25-15	1c	●	●			
	1. The Liver							

Topic Outline				A/V Resources				
Objectives	**Chapter 25** **Metabolism and Energetics** (page 3 of 4)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	2. Adipose Tissue							
	3. Skeletal Muscle, Neural Tissue, and Other Peripherial Tissues							
2a	B. The Postabsorptive State	25-16,17		●	●			
	1. The Liver							
	2. Adipose Tissue							
	3. Skeletal Muscle							
	4. Other Peripheral Tissues							
	5. Neural Tissue							
2b	**VIII. Diet and Nutrition**							
	A. Food Groups and Food Pyramids	25-18	6e	●	●			
	B. Nitrogen Balance							
	C. Minerals		5a					
	D. Vitamins		5a					

Topic Outline				A/V Resources				
Objectives	**Chapter 25** **Metabolism and Energetics** (page 4 of 4)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	1. Water-Soluble Vitamins							
3	E. Diet and Disease		2a					
	IX. Bioenergentics							
	A. Food and Energy							
2c	B. Metabolic Rate							
2d	C. Thermoregulation							
	1. Mechanisms of Heat Transfer	25-19			•			
	2. The Regulation of Heat Gain and Heat Loss							
	3. Sources of Individual Variation							
	4. Fevers							

CHAPTER 26

The Urinary System

Introduction

Your students will probably be familiar with the idea that the presence of protein in the urine is a sign of pathology. Recent findings have modified this "rule of thumb" in some interesting ways. This work is discussed by Mogensen in a recent article (*Scientific American Science and Medicine*, May/June 1996). New techniques have extended the range of sensitivity of protein measurements. Using this technique it was found that there is a small amount of protein in the urine of normal individuals. What is perhaps more interesting is that these measurements allow diagnosis of certain pathologies at an earlier stage the previously possible. The two diseases discussed in this article are diabetes and hypertension. Both of these conditions can lead to serious renal pathology. The sensitive measurement of urine protein allows early detection of the onset of such problems. The damage induced by diabetes can to some extent be minimized or slowed by using ACE inhibitors. This whole story is a nice example of the interplay between different organ systems.

Instructional Goals/Learning Objectives

1. To familiarize students with the basic functions of the urinary system, and the relationships between this and other systems.

   a. *Identify the components of the urinary system and describe the functions performed by each.*
   b. *Describe the structural features of the kidney.*
   c. *Describe the structure of the nephron and the processes involved in the formation of urine.*
   d. *Identify the major blood vessels associated with the kidney, and trace the path of blood flow through the kidney.*
   e. *List and describe the factors that influence filtration pressure and the rate of filtrate formation.*
   f. *Describe the normal characteristics, composition, and solute concentrations of a representative urine sample.*
   g. *Describe the structures and functions of the ureters, urinary bladder, and urethra.*
   h. *Discuss the voluntary and involuntary regulation of urination and details of the micturition reflex.*

2. To present an integrated picture of the histological characteristics and physiological activities of each portion of the nephron.

   a. *Identify the types of transport mechanisms found along the nephron, and discuss the reabsorptive or secretory functions of each nephron segment and collecting system.*

3. To understand the mechanism responsible for countercurrent exchange and countercurrent

multiplication.

a. *Explain the role of countercurrent multiplication in the formation of a concentration gradient in the medulla.*
b. *Describe how antidiuretic hormone and aldosterone influence the volume and concentration of urine.*

❑ Teaching Strategies

1. Analogies

a. The location of the kidneys demonstrates the difference between the peritoneal cavity and the abdominal cavity. They lie within the abdominal cavity with the rest of the abdominal organs, but they are separated from those organs by the parietal peritoneum. Imagine a room as a cavity. If you put wallpaper on the walls of the room, you would be covering the walls with a decorative "membrane" (parietal peritoneum). If you did not bother to remove the pictures from the walls and papered over them, then the pictures would still be in the room, but they would hang behind the paper (retroperitoneal) (CONTRIBUTED BY LINDA BANTA, SIERRA COLLEGE). The only place the kidneys are "attached" is at the blood vessels on their medial surface. This makes the overlying peritoneum and connective tissues especially important for maintaining their position against the abdominal wall and preventing ptosis.

b. Compare the size of the kidney to the size of your hand.

c. As you describe the cortex, medulla, and orientation of the pyramids, emphasize that they are three dimensional (most sectional views imply that the pyramids are flat). The cortical region can be easily distinguished from the medullary region. It appears grainy, while the medulla looks like strands of combed hair. (The cortex has a different structural appearance as compared with the medulla, could it be because it has a different function?) Compare the orientation of the pyramids within the renal lobes to holding a bundle of ice cream cones (the pointed kind). The mounded scoop of ice cream represents the cortical region, and the cone represents the medullary region. The tip of the cone is the papilla, and there are several papillae coming together at the sinus (pelvis). Each cone is separated from the next by the paper wrapped around it (renal columns). The papillae of the cones press into the balloon-shaped sinus (without popping it of course), much the way you might press your finger into the surface of a balloon. The membrane of the balloon surrounds the papilla like a cup-shaped funnel (calyx), ready to catch the drops of urine as they drip through the ducts of the papilla.

d. As you introduce the three steps involved in urine formation, emphasize the direction of flow relative to inside (IN) the blood vs. outside (OUT) the blood:

process	from-to
filtration	IN - OUT
reabsorption	OUT - IN
secretion	IN - OUT

The sum total of the right hand column = urine; i.e., everything that is filtered and secreted OUT minus whatever is reabsorbed back IN. It does not sound "logical" to students to filter everything out at the glomerulus just to turn around and reabsorb 70 percent of that filtrate. Try the following analogy in order to illustrate (in an introductory sense) the three processes of urine formation. Suppose I give you a trash çan full of marbles (being in the trash can represents being in the blood). The marbles are of all different sizes and colors. I say to you, "I would like you to throw away all those marbles that are large and yellow or small and red. I will be back in ten minutes to see if you're done." What do you do first? Dump all the marbles out onto the table (filtration). Then you start grabbing all the marbles that are not large and yellow or small and red, and you put them back into the trash can (reabsorption). When you finish, you take a quick look through the marbles in the trash can to make sure you didn't miss any. Sure enough, just as I walk back into the room, you spot a small, red marble that was overlooked. You take the marble out of the can and lay it on the table (secretion).

e. Students do not really appreciate the logic behind urinalysis; i.e., examining what the body is throwing away as a way of determining what must be going on inside. Point out that they make those kinds of deductions all the time. For example: You are taking a walk through your neighborhood, and it just happens to be trash pick-up day. As you walk past one house, you see at the end of the driveway an old chair, a broken tennis racket, a card table with a bent leg, and a child's doll, minus the head. What do you remark? "The Smiths must have been cleaning out their basement this weekend." A few houses down, you spot a squirrel sneaking crumbs out of a large bakery box. You notice some burnt candles in the bottom of the box. Overflowing the trash can are ribbons and wrapping paper. On the curb next to the can, you see numerous boxes that once held a variety of children's toys. And your comment? "I didn't realize it was Eddie's birthday." Finally, around the corner you notice a third house. There are dozens of crushed beer cans on the front lawn, empty pizza boxes laying on the driveway, and toilet paper hanging from the trees. "They had some terrific party!"

2. Demonstrations

3. Vocabulary Aids

4. Applications

5. Common Student Misconceptions/Problems

a. Students tend to have the misconception that the urinary system has something to do with the digestive system. Perhaps it is because urine exits the body in the same general vicinity as feces, at approximately the same time, into the same receptacle, and they are flushed from sight with a single flip of the wrist. The students are always surprised to discover that freshly voided urine is a sterile liquid and as such, was used to wash the wounds of soldiers in the field. (Yuck!) To connect the function of the urinary system with the blood never occurs to them, in spite of the fact that the kidneys have their own, private "access highway" directly off of the aorta. (Structure related to Function, what?). Overcoming this misconception will be your first challenge. Before starting with the details regarding the anatomy and physiology of the kidney, draw the kidney as a "black box." Point out that on one side of that box, blood goes in and blood comes out. On the other side of the box, urine comes out. What kind of magic activities must be going on in there? Could the urine be a result of whatever happens to the blood while it's in the magic box? How could that be? Certainly, urine does not resemble blood! What about this analogy: You see a line of shabbily clothed people marching into the entrance of a building. Coming out the exit are the same people, only now they are dressed as if they stepped from the pages of the latest fashion magazine. Around the back of the building, you catch a glimpse of old, worn-out clothes being loaded onto trucks and hauled away to the dump. What do you suppose is happening in that building? The overall "point" of the urinary system is the same. Entering the kidney is "shabby" blood, blood that has an inappropriate amount of water, ions (Na^+, K^+, Cl^-, etc.), H^+ (pH), nitrogenous and soluble metabolic wastes. Exiting the kidney is blood that has been completely "spiffed up." Coming out the back door is urine. Now, what do you suppose is happening in the kidney? (A nice segue to the first topic: The Functions of the Urinary System).

b. Before describing the anatomy of a single nephron, bring Figures 26-7(c) or 26-8 to the students' attention. Point out how twisted and coiled the tubule of the nephron is (Figure 26-7), and how it is completely surrounded by blood vessels (Figure 26-8.) As you examine the parts of the nephron tubule detailed in Figure 26-5, stress that this is a representative picture and that the blood vessels have been removed, and the tubule has been unnaturally "spread out" to make initial examination less complicated. Since many diagrams of nephrons appear like this, the students often get a mistaken impression that 1) the blood vessels are somehow separate from the nephron, supporting their original misconception that the blood has nothing to do with the urinary system, and 2) that the proximal and distal convoluted tubules get their names exclusively based upon their physical proximity to the glomerulus, and not on which tube is the first to receive the filtrate. This perception results in misidentification of the descending and ascending limbs when showing a nephron in its proper orientation, with the loop of Henle twisted so that the distal convoluted tubule touches the afferent arteriole (the JGA).

c. Students tend to confuse NFP, GFR, and RC. Take it one step at a time. Explain that NFP is the result of the net hydrostatic pressure being larger than the net osmotic pressure. NFP = HP - OP. Ask them what would happen to NFP if hydrostatic pressure increased? If osmotic pressure increased? Now explain that NFP measures the force that drives the fluid out of the capillary across the membrane, but GFR

measures the volume of fluid that is filtered every minute. GFR is a function of the NFP over a period of time. GFR = ml/min. GFR must be protected above all else! What would happen to GFR if NFP increased? decreased? RC is a way of measuring how much of a substance actually is "cleared" from the plasma (as a result of filtration) and ends up making it all the way through to become urine. That is, the amount filtered, minus what ever gets reabsorbed, plus whatever is secreted back into the filtrate. This equals how much stays in the urine (which is the same thing as saying how much was cleared from the plasma)? Creatinine is a substance that is completely filtered OUT, and none of it gets reabsorbed back IN. So it is cleared from the plasma as fast as the glomerulus can filter it, GFR = RC. That is what makes it an important diagnostic tool for determining GFR. If the amount of creatinine in the urine drops below normal, it must mean that the GFR has decreased. Uh-oh!

d. Occasionally, students mix up the action of ADH with its effect of making the urine more concentrated (they somehow equate ADH with diluted urine). Ask them what the effect would be if they were to take a "water pill," i.e., a diuretic. If a diuretic makes you lose water, than an anti-diuretic will make you retain water. If you retain water, it stays in the blood; hence, the urine is more concentrated.

6. Lecture ideas

a. The glomerular capillaries represent one of the rare times that an arteriole brings blood to a capillary and an arteriole (not a venule) takes blood away from the capillary. Clarify that the renal corpuscle is composed of the glomerulus AND Bowman's capsule. Stress that anything that crosses from the capillary to the space must go through three structures, the wall of the capillary, the lamina, and the parietal membrane of Bowman's capsule. The result of that crossing is that the substance, now called filtrate, has moved FROM INSIDE TO OUTSIDE. It is vital to introduce this inside/outside concept as soon as possible, so that the students begin to understand that anything that gets to the tubule and stays in the tubule becomes urine. The only way to reclaim items from the filtrate is to reabsorb those items back into the blood.

b. Point out that the filtration pressures that were examined in capillary dynamics are the same pressures governing filtration across the glomerular membrane into the capsular space; i.e., net hydrostatic pressure pushing fluid out of the blood exceeding net osmotic pressure drawing fluid back into the blood. Blood cells and plasma proteins are too large to fit through the capillary fenestrations and the filtration slits, so they stay in the blood.

c. It might be helpful to start discussion of the countercurrent multiplication mechanism by explaining that the mechanism relies on some basic properties of the tubules:

1) The structure of the cells of the loop of Henle varies in the length of the loop. Thus, the loop is not equally permeable throughout its length.
2) The descending limb is freely permeable to water, and impermeable to sodium and other solutes.

3) The ascending limb is impermeable to water, but can actively transport sodium and chloride ions out of the tubule.
4) There is the establishment of a concentration gradient in the interstitial fluid of the kidney, making the ISF of the cortex isotonic as compared to the fluid in the tubule (300 mOsm). In the deep medulla, the ISF is hypertonic (1200 mOsm).
5) The structural arrangement of the loop of Henle and vasa recta is such that the tubes and vessels are in close proximity to each other. Both have a countercurrent arrangement.

Explain the entire process without regard to ADH or aldosterone, just to get the basics down. Then go back to "fine tune" with the control mechanisms.

d. Since the ureters enter the posterior, inferior surface of the bladder, they do not need a sphincter muscle at the junction. Urine continues to flow into the bladder, until the bladder becomes distended enough that the pressure closes off the ureteral opening.

❑ Answers to End of Chapter Exercises

Level 1: Reviewing Facts and Terms

1. c
2. a
3. a
4. b
5. c
6. d
7. a
8. d
9. b
10. c
11. c
12. d
13. b
14. b

15. The urinary system performs vital excretory functions and eliminates the organic waste products generated by cells throughout the body.

16. The urinary system includes the kidneys, ureters, urinary bladder and urethra.

17. Renal corpuscle (glomerulus/Bowman's capsule) ⇒ proximal convoluted tubule ⇒ loop of Henle ⇒ distal convoluted tubule ⇒ collecting tubule ⇒ collecting duct ⇒ papillary duct ⇒ renal pelvis (urine).

18. Proximal convoluted tubule: reabsorbs all of the useful organic substrates from the filtrate. Loop of Henle: reabsorbs over 90% of the water in the filtrate. Distal convoluted tubule: secretes into the filtrate waste products that were missed by the filtration process.

19. The lamina densa is an elaborate basement membrane surrounding the capillaries of the glomerulus. During filtration, it restricts the passage of large plasma proteins, but permits the movement of smaller molecules, including albumin, many organic nutrients, and ions.

20. The juxtaglomerular apparatus is an endocrine structure that secretes two hormones, renin and erythropoietin.

21. Renal artery ⇒ segmental arteries ⇒ interlobar arteries ⇒ arcuate arteries ⇒ interlobular arteries ⇒ afferent arterioles ⇒ glomerular capillaries ⇒ efferent arterioles ⇒ peritubular capillaries and vasa recta ⇒ interlobular veins ⇒ arcuate veins ⇒ interlobar veins ⇒ renal vein.

22. (1) Filtration - blood pressure forces water and small solutes across a filtration membrane. (2) Reabsorption - removal of water and solute molecules from the filtrate after it enters the renal tubules. (3) Secretion - transport of solutes from the peritubular fluid, across the tubular epithelium, and into the tubular fluid.

23. In peripheral capillary beds, angiotensin II causes powerful vasoconstriction, elevating pressures in the renal arteries and their tributaries. At the nephron, angiotensin II causes constriction of the efferent arteriole, elevating glomerular pressures and filtration rates. At the PCT it stimulates reabsorption of sodium ions and water. In the CNS, angiotensin II triggers the release of ADH, stimulating the reabsorption of water in the distal portion of the DCT and the collecting system, and causes the sensation of thirst. At the adrenal gland, angiotensin II stimulates the secretion of aldosterone by the cortex and epinephrine by the medulla oblongata. The aldosterone accelerates sodium reabsorption in the DCT and

cortical portion of the collection system. Epinephrine causes increased heart rate and force of contraction, elevating renal blood pressure.

24. Ureters, urinary bladder and urethra.

Level 2: Reviewing Concepts

25. d
26. c
27. d
28. b
29. c
30. a
31. a

32. 85% of nephrons are called cortical nephrons because they are found in the superficial cortex of the kidney. The remaining 15% (the juxtamedullary nephrons) are located closer to the medulla, and their loops of Henle extend deep into the renal pyramids.

33. Net filtration pressure = (glomerular hydrostatic pressure minus capsular hydrostatic pressure) minus (blood colloid osmotic pressure), i.e:

$$NFP = (GHP - CsHP) - BCOP$$

34. autoregulation at the local level; hormonal regulation initiated by the kidneys; autonomic regulation, (sympathetic division of the ANS).

35. Renal threshold is the plasma concentration at which a specific compound or ion will begin appearing in the urine.

36. As a result of facilitated diffusion and cotransport mechanisms 99% of the glucose, amino acids and other nutrients are reabsorbed before the filtrate leaves the PCT. Reduction of the solute concentration of the tubular fluid occurs due to active ion reabsorption of sodium, potassium, calcium, magnesium bicarbonate, phosphate, and sulfate ions. The passive diffusion of urea, chloride ions, and lipid-soluble materials further reduces the solute concentration of the tubular fluid, and promotes additional water reabsorption.

37. (1) The countercurrent multiplier is an efficient way to reabsorb solutes and water before the tubular fluid reaches the DCT and collecting system. (2) It establishes a concentration gradient that will permit the passive reabsorption of water from the urine in the collecting system.

38. In the DCT, collecting tubule and collecting duct, sodium-chloride cotransport and aldosterone-stimulated reabsorption of sodium ions adjusts the osmolarity of the filtrate. The osmotic concentration of the urine is controlled by variations in the water permeabilities of the distal portion of the DCT, the collecting tubules and the collecting ducts. The segments are impermeable to water unless exposed to antidiuretic hormone (ADH) from the posterior pituitary. At normal concentrations of ADH the distal portions of the DCT and the collecting tubules and ducts are somewhat permeable to water, and

there is an osmotic flow of water out of the urine as it passes along the collecting ducts. Under these conditions the urine entering the minor calyx has an osmolarity approaching 1200 milliosmoles/liter.

39. The urge to urinate usually appears when the bladder contains about 200 ml of urine. The micturition reflex begins to function when the stretch receptors have provided adequate stimulation to the parasympathetic motor neurons. The activity in the motor neurons generates action potentials that reach the smooth muscle in the wall of the urinary bladder. These efferent impulses travel over the pelvic nerves, producing a sustained contraction of the urinary bladder.

Level 3: Critical Thinking/Application

40. Truck drivers may not urinate as frequently as they should. Resisting the urge to urinate can result in urine backing up into the kidney. This puts pressure on the kidney tissues, which can lead to tissue death and ultimately to kidney failure.

41. A single sample is useful in detecting the presence or absence of specific solutes (such as glucose). A single sample is less useful when one wants to see how much fluid is being lost via urination, or the amount of some substance (urea, creatinine, etc.) lost per day. This is because the amount of water reabsorbed from the filtrate may change from moment to moment, making the concentration in any one sample variable. The concentration of a solute in a single sample is much more variable than the amount excreted in a 24 hour period.

42. Caffeine increases the glomerular filtration rate (GFR) by causing vasodilation of the glomerular capillaries. The increase in rate of flow through the renal tubule reduces the time available for reabsorption of solutes. The alcohol acts as a diuretic. It inhibits ADH secretion, resulting in excess loss of water by formation of dilute urine. The resulting dehydration leads to decreased secretion by body glands, including the salivary glands, which makes the mouth dry.

43. Susan may have a urinary tract infection; her urine may contain blood cells and bacteria. She is more likely to have this problem than her husband because the urethral orifice in females is closer to the anus, and the urethral canal is short and opens near the vagina. Both regions normally harbor bacteria and these may easily reach the urethral entrance (often during sexual intercourse).

44. By decreasing the active transport of sodium and chloride ions from the loop of Henle, the drug will produce a more concentrated filtrate and a less concentrated interstitial fluid surrounding the loop of Henle. This combination of factors will lead to the production of a large volume of urine for two reasons. First, the more concentrated filtrate will retain water due to the increased osmolarity. Second, less water will leave the descending limb because the osmotic gradient will not be as great. The increase in urine volume will lower blood volume, and since there is a direct relationship between blood volume and blood pressure, if the blood volume decreases, the blood pressure will decrease (assuming no other critical factors change).

45. Arteriosclerosis contributes to hypertension (high blood pressure). The hypertension would trigger a baroreceptor reflex that would lead to a decrease in the level of ADH in the blood. Assuming that the arteriosclerosis is affecting all of Carlos' large arteries including the renal arteries, the stiffening of the vessels would decrease the blood flow to the kidneys thus triggering the release of renin from the juxtaglomerular apparatus. The renin would catalyze the conversion of angiotensinogen into angiotensin I and the angiotensin I would be converted into angiotensin II at the lungs. The angiotensin II would stimulate the secretion of aldosterone which would increase sodium and water reabsorption thus increasing blood volume. The increase in blood volume would add to the hypertension further decreasing the levels of ADH.

46. Since mannitol is filtered but not reabsorbed, drinking a mannitol solution would lead to an increase in the osmolarity of the filtrate. This would cause less water to be reabsorbed and result in an increased volume of urine being produced.

47. Carbonic anhydrase catalyzes the reaction that forms carbonic acid, a source of hydrogen ions that are excreted by the kidneys. Hydrogen ion excretion is accomplished by an antiport system in which sodium ions are exchanged for hydrogen ions. Since there would be fewer hydrogen ions available, less sodium would be reabsorbed and this would contribute to an increased osmolarity of the filtrate. This is turn would lead to an increased volume of urine and more frequent urination.

❑ Media Lab Instructor Notes

Web addresses often change. To avoid dead links, we are listing the keywords in parentheses next the to Web Explorations. Simply go to the Companion Website (http://www.prenhall.com/martini), select the Fifth Edition of Fundamentals of Anatomy and Physiology and search using the key word to locate the current address.

Animations (Website)

- Figure 26-10—Animation in play / next format. Transport activities at the PCT; suitable for lecture demonstration of ion transport at PCT.
- Figure 26-12—Animation in play / next format. Tubular secretion and solute reabsorption at the DCT; suitable for lecture demonstration of DCT functions or self study after presentation.
- Figure 26-14—Animation in play / next format. Major steps in the production of a concentration gradient; suitable for lecture demonstration of loop of Henle (web exploration 3) or self-study tool after presentation.

Animations (CD-ROM)

- Rotating 3-dimensional image of kidney corresponding to Figure 26- 3 Structure of the kidney.

Web Explorations (Overview)

Web Exploration 1 **(URINARY QUIZZES)**

- *Goal*—review, practice
- *Description of page*—WebAnatomy quiz page created by Dr. Murray Jensen
- *Expectations of student behavior*—study text, click on quizzes, answer and check answers
- *Instructor's role*—assist in interpretation of diagrams, provide hints for naming structures
- *Special notes or further uses of exploration*—home page link to WebAnatomy is helpful as self study aid.

Web Exploration 2 **(URINALYSIS)**

- *Goal*—critical thinking, information application
- *Description of page*—University of Utah Medical school lab pages, link to other labs at top and bottom
- *Expectations of student behavior*—read short introduction, read through case study, discuss implications with classmates
- *Instructor's role*—provide normal ranges of urinalysis tests, discuss implications of each test result
- *Special notes or further uses of exploration*—outside links not terribly useful, make sure students work on case before clicking on answers

Additional Web Explorations

Should the two explorations found in the text not answer your needs, a third exploration is provided below. Your students do not have direct access to this exploration. You must provide them the address and information in the following paragraph.

Web Exploration 3
Estimated time for completion = 10 minutes

The role of the nephron in maintaining homeostasis is to monitor and control fluid and ion levels. Congestive heart failure is a fluid imbalance that is notoriously treated with loop diuretics. This treatment capitalizes on the normal functioning of the nephron by increasing the movement of sodium and water into and out of the nephron. Using what you know of the function of the **LOOP OF HENLE**, visit this site (http://www.mmhc.com/nhm/articles/NHM9910/graff.html) and read the article entitled "Loop Diuretics in the Management of Congestive Heart Failure in the Elderly." Prepare an outline of the article, listing the drugs used and their actions. Include a brief explanation of how that drug helps congestive heart failure.

Web Exploration 3 (**LOOP OF HENLE**)

- *Goal*—critical thinking, concept application
- *Description of page*—Nursing Home Medicine magazine page with top and bottom links
- *Expectations of student behavior*—read, prepare outline
- *Instructor's role*—thoroughly explain ion movement through the loop of Henle, direct student thoughts as they work through article
- *Special notes or further uses of exploration*—links to practical nursing information, article includes references that can be accessed in traditional libraries (good old fashioned print!)

Objectives	TOPIC OUTLINE **Chapter 26** **The Urinary System** (page 1 of 3)	Figures	Strategies	A/V RESOURCES: Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	I. Introduction		5a					
1a	**II. Organization of the Urinary System**	26-1		●	●		●	●
1b	**III. The Kidneys**	26-1,2,3	1a	●	●	●		●
	A. Superficial Anatomy of the Kidneys	26-3,4	1b	●	●		●	●
	B. Sectional Anatomy of the Kidneys	26-4a	1c	●	●			●
1d	C. The Blood Supply to the Kidneys	21-26a, 26-5		●	●		●	●
	D. Innervation of the Kidneys							
1c	E. The Nephron	26-5,6,7	5b	●	●			●
	1. The Renal Corpuscle	26-8	6a	●	●			●
	2. The Proximal Convoluted Tubule	26-6		●	●			●
	3. The Loop of Henle	26-7		●	●			●
	4. The Distal Convoluted Tubule	26-8b		●	●			●
	5. The Collecting System	26-6		●	●			●
	IV. Renal Physiology							

Topic Outline				A/V Resources				
Objectives	**Chapter 26** **The Urinary System** (page 2 of 3)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	A. Basic Principles of Urine Formation		1d				●	
1e	B. Filtration	26-8d,9a	6b		●		●	
	1. Filtration Pressures	26-12,13		●	●			
	2. Glomerular Filtration Rate		5c					
	3. Controlling the GFR	26-10		●	●			
2a	C. Reabsorption and Secretion						●	
	1. Carrier-Mediated Transport	3-9,10,11 23-21 24-14		●	●			
	2. The Proximal Convoluted Tubule	26-11		●	●	●		
3a	3. The Loop of Henle and Countercurrent Exchange	26-12	6c	●	●			
3b	4. The Distal Convoluted Tubule	26-13		●	●	●		
	5. The Collecting System	26-13bc	5d	●	●			
	6. The Control of Urine Volume and Osmotic Concentration	26-14		●	●			
3a	D. The Function of the Vasa Recta						●	

Objectives	TOPIC OUTLINE: **Chapter 26 The Urinary System** (page 3 of 3)	Figures	Strategies	A/V RESOURCES: Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	E. Summary: Renal Function	26-15			●	●		
1f	F. The Composition of Normal Urine							
1g	**V. Urine Transport, Storage, and Elimination**	26-17			●			
	A. The Ureters	26-2b,3,4,18	6d	●	●			
	1. Histology of the Ureters	26-19a		●	●			●
	B. The Urinary Bladder	26-18c		●	●			
	1. Histology of the Urinary Bladder	26-19b		●	●			●
	C. The Urethra	26-18		●	●			
	1. Histology of the Urethra	26-19c		●	●			●
1h	D. The Micturition Reflex and Urination	26-20			●			
	VI. Aging and the Urinary System							
	VII. Integration with Other Systems	26-21		●	●			

CHAPTER 27

Fluid, Electrolyte, and Acid-Base Balance

Introduction

This is an excellent "cap stone" topic for the entire course. Nearly every organ system is involved in homeostatic control of these variables. Also, the control of the fluid, electrolytes and acid-base are all interconnected. It might be a good initial strategy to describe a specific acid-base disorder or two with which the students might be familiar. List the basic problems and symptoms. Ask the students to hypothesize about the fundamental problem, its diagnosis, and how it might be treated. Then tell them how it is treated. Mention that you will come back to these examples at the end of the section and they will understand them much better.

Instructional Goals/Learning Objectives

1. To discuss the patterns of body fluid distribution, stressing the integration and interplay among the lymphatic, cardiovascular, respiratory, digestive, and urinary systems.

    a. *Compare the composition of the body fluids.*

2. To review the homeostatic mechanisms that regulate body fluid volume and composition.

    a. *Explain the basic concepts involved in fluid and electrolyte regulation.*
    b. *Identify the hormones that play important roles in regulating fluid and electrolyte balance, and describe their effects.*
    c. *Discuss the mechanisms by which sodium, potassium, calcium, and chloride are regulated to maintain electrolyte balance in the body.*

3. To provide a working knowledge of the mechanics of acid-base balance and a familiarity with the terms acidosis and alkalosis, and the clinical significance of such conditions.

    a. *Explain the buffering systems that balance the pH of the intracellular and extracellular fluids.*
    b. *Describe the compensatory mechanisms involved in the maintenance of acid-base balance.*

4. To describe the treatment of acidosis and alkalosis in terms of the major buffer systems.

    a. *Identify the most frequent threats to acid-base balance, and explain how the body responds when the pH of body fluids varies outside normal limits.*

❑ Teaching Strategies

1. Analogies

a. As you describe the body fluid compartments, refer to the analogy presented in Chapter 19. Fluid compartments of the body are like the air compartments of an inflatable air mattress. Within the system, fluid moves freely from one compartment to another depending upon homeostatic "pressures," just as the air within the mattress moves from one compartment to another as you shift your weight and put pressure on different areas. As long as the overall volume of fluid filling the body (or the mattress) remains the same; it just shifts position.

b. Stress that although fluid and electrolytes are opposite sides of the same coin, the mechanisms for controlling their balances are different. Hence, a distinction must be made between the two, especially when examining problems that arise in a clinical setting. When you walk, your left leg's activity certainly has an influence over your right leg's activity (and vice versa). It is difficult to talk about one without looking at the other, when your left leg is forward, your right leg is behind; when your right leg is off the ground, your left leg is on the ground, etc. However, the bones, muscles, and nerves that control the left leg during the balance needed for walking are separate from those that control the right leg; and if a patient comes in with a hamstring injury on the right leg, you wouldn't think to treat the left femur! (You might provide crutches that help maintain the balance while the right leg is out of commission).

2. Demonstrations

3. Vocabulary Aids

4. Applications

5. Common Student Misconceptions/Problems

a. Obviously, to talk about electrolyte balance, you must talk about electrolyte concentrations. Remind the students that concentrations are NOT simply expressions of numbers of molecules or weight of a solute, but they are expressions of the solute to solvent ratio in a given volume. This is a fact that students have a hard time visualizing (or remembering), no matter how many times it is explained to them. Point out that the concentration of a solute can be changed by adding or taking away the solute OR by adding or taking away the solvent. Those two factors have an inverse relationship to each other. That is, you can make an isotonic solution hypertonic by adding electrolytes OR by removing the water. You can make an isotonic solution hypotonic by removing electrolytes OR by adding water. Perhaps a table will help:

	solute	solvent
increase	more concentrated (hypertonic)	less concentrated (hypotonic)
decrease	less concentrated (hypotonic)	more concentrated (hypertonic)

If you have the students examine Figure 27-4, point out that more concentrated = molecules closer together; less concentrated = molecules further apart. The molecules will be closer together or further apart depending upon how many molecules (solute) there are OR how much volume there is (solvent). That is why electrolyte balance can influence and be influenced by water balance.

Suppose I put a teaspoon of salt in a cup of water and a teaspoon of salt in a two-liter bottle of water. Which water would taste saltier? If they both have the same amount of salt, why would they taste differently?

b. Review the terms in Table 27-1. Point out that sometimes "acidity" or "alkalinity" can be used as relative terms. For example, the pH of the blood is 7.35-7.45 (a slightly alkaline pH). If the pH were to drop to 7.25, we would refer to that as acidosis, or we would say that the blood pH was too acidic, even though 7.25 is still slightly alkaline. It might also help to remind the students that a unit change in pH represents a ten-fold change in hydrogen ion concentration. A solution with a pH of 8 has ten times the concentration of hydrogen ions of one with a pH of 7, and one-tenth the concentration of hydrogen ions of one with a pH of 9.

6. Lecture ideas

a. Carefully examine Figure 27-2 with the students. It confirms facts of which they are already aware, and it alerts them to important details to come.

1) Examining the cations, the concentrations of sodium are higher outside of the cell, while concentrations of potassium are higher inside the cell (remember membrane potentials?). Carbonic acid is about the same across the board

2) Among anions, chloride ion concentrations are higher outside the cell, while phosphate ion concentrations are higher inside the cell. As before, carbonic acid is about the same across the board (along with bicarbonate).

3) The following apparent contradiction may escape the students' observation, so ask, "How can carbonic acid be listed in BOTH the cation and anion columns? Which is it?" Even if you chose not to address this point until the discussion of buffers, it helps to alert the students ahead of time, and "warn" them that it will be an important point to remember.

4) It should not be a surprise that protein concentrations are higher inside cells, since that is where they are made and primarily used. Point out also that proteins exist in higher concentrations in the plasma than in the ISF (remember plasma proteins and the role they play in osmotic pressure within capillaries?). What the students may not understand (or even question), is why proteins are listed as anions. Again, you may want to save your explanation until the discussion of buffers, but making reference to it now will alert them of its impending importance.

b. Remind the students that the effects of ADH, aldosterone, renin-angiotensin, and ANP were discussed when discussing hormones and kidney function. Now the students have the opportunity to view those same mechanisms from the perspective of fluid and electrolyte balance. As you discuss the receptors, their locations. and the response of the target organs, draw out the pattern of control in the typical reflex arc that has been discussed in previous chapters.

c. As you discuss the dissociation and association of carbonic acid, stress that the reaction is reversible, and is driven in either direction depending upon conditions in the environment. Emphasize the relationship that pH has with carbon dioxide concentrations; i.e., as CO_2 levels go up, pH goes down (H^+ concentration increases). Ask the students if they can now answer the question that was posed during the discussion of Figure 27-2: "How can carbonic acid be listed in BOTH the cation and anion columns?"

d. Indicate that, regardless of the specific buffering system, there are always two components involved: a weak acid and a weak base. Ask the students to explain the difference between a weak acid and a strong acid or a weak base and a strong base. Ask them which would be easier for the body to deal with in terms of controlling fluxes of hydrogen ion concentrations, weak acids and bases or strong acids and bases. Explain that the point of any buffering system is to convert a strong acid environment into a weak one or a strong base environment into a weak one. It accomplishes this task by getting rid of H^+ from the environment or releasing H^+ into the environment. Remember: hydrogen ions do not have an effect on pH unless they are hanging loose. So the buffers must be weak proton donors (weak acids) and weak proton acceptors (weak bases). Hence, all buffering systems have two components: a weak acid and a weak base. Offer the following generic equations as a way of establishing the pattern:

$$\text{strong acid} + \text{weak base} \Longrightarrow \text{weak acid} + \text{salt}$$

$$\text{strong base} + \text{weak acid} \Longrightarrow \text{weak base} + \text{water}$$

As you explain each buffering system, identify the weak acid and the weak base, designate its primary area of influence (ICF or ECF), and give a specific example showing the buffering system "in action."

e. Since the kidney can generate urine with a pH anywhere from 3 to as high as 8, urine makes the perfect "toxic waste dumping site" for excess hydrogen ions in the blood.

f. Stress the differences between acidosis/alkalosis as a result of respiratory disturbances versus acidosis/alkalosis as a result of metabolic disturbances. Associate carbon dioxide levels in ECF with respiratory acid-base disorders, but bicarbonate ion levels in ECF with metabolic acid-base disorders. Point out that the end point may be the same (i.e., acidosis or alkalosis), but if you don't know what is causing the problem, you can't treat it. If a patient experiencing the symptoms of acidosis is treated by inducing bronchodilation, it won't do much good if the acidosis is a result of a metabolic disturbance, you might have treated the symptoms, but you've done nothing about the source of those symptoms.

❑ Answers to End of Chapter Exercises

Level 1: Reviewing Facts and Terms

1. l
2. h
3. r
4. a
5. t
6. c
7. o
8. b
9. q
10. e
11. f
12. s
13. d
14. j
15. i
16. k
17. m
18. g
19. p
20. n
21. c
22. c
23. a
24. b
25. d
26. b
27. d
28. d
29. d
30. b
31. a

32. A fluid shift is a water movement between the ECF and ICF; this movement helps prevent drastic variations in the volume of the ECF. Changes in the osmolarity of the ECF can cause fluid shifts. If the ECF becomes more concentrated (hypertonic) with respect to the ICF, water will move from the cells into the ECF until equilibrium is restored. If the ECF becomes more dilute (hypotonic), water will move from the ECF into the cells. Changes in osmolarity can result from water loss (such as excessive perspiration, dehydration, vomiting, or diarrhea); water gain (drinking pure water, administering hypotonic solutions intravenously); and changes in electrolyte concentrations (such as sodium).

33. (1) Antidiuretic hormone - stimulates water conservation at the kidneys and stimulates the thirst center. (2) Aldosterone - determines the rate of sodium absorption and potassium secretion along the DCT and collecting system of the kidney. (3) Atrial natriuretic peptide - reduces thirst and blocks the release of ADH and aldosterone.

34. Aldosterone promotes sodium conservation in exchange for potassium excretion in the urine.

35. a) A volatile acid is an acid that can leave solution and enter the atmosphere; carbon dioxide is an important volatile acid. b) A fixed acid is an acid that does not leave solution. Once produced, it remains in body fluids until excreted at the kidneys. Sulfuric acid and phosphoric acid are the most important fixed acids. c) An organic acid contains carbon and is usually a participant in or byproduct of cellular metabolism. Important examples include lactic acid and ketone bodies. Volatile acids, such as carbon dioxide, probably represent the greatest threat to acid-base balance, since CO_2 concentration is the most important factor affecting the pH of body tissues.

Level 2: Reviewing Concepts

36. a
37. d
38. d
39. a
40. b
41. b
42. c
43. a

44. Fluid balance refers to a state in which the amount of water gained each day is equal to the amount lost to the environment. It is vital that the water content of the body remain stable because water is an essential ingredient of cytoplasm and accounts for about 99% of the volume of extracellular fluid. Electrolyte balance exists when there is neither a net gain nor a net loss of any ion in body fluids. It is important that the ionic concentrations in body water remain within normal limits; if levels of calcium or potassium become too high, for instance, cardiac arrhythmias can develop. Acid-base balance exists when the production of hydrogen ions precisely offsets their loss. The pH of body fluids must remain within a relatively narrow range; variations outside this range can be life-threatening.

45. To go from mg/dl to mmol/l multiply by 10 and divide by the atomic weight (35.5 g/mol) of chlorine.

$$(250 \text{ mg/dl} \times 10 \text{ dl/l})/(35.5 \text{ g/mol}) = 70.42 \text{ mmol/l}$$

46. "Drink plenty of fluids" is physiologically sound advice because the temperature rise accompanying a fever can also increase water losses. For each degree the temperature rises above normal the daily water loss increases by 200 ml.

47. Whenever sodium gains exceed sodium losses, the volume of the ECF increases, but its osmolarity remains the same. When sodium losses exceed gains, the ECF volume decreases, but there is no significant change in the osmolarity of the ECF.

48. A buffer system is a combination of a weak acid and its dissociation products which helps control the level of acids produced during normal metabolic operations. The three major buffer systems in body fluids are:

(1) Protein buffer systems - these depend on the ability of amino acids to respond to changes in pH by accepting or releasing hydrogen ions. If the pH rises, the carboxyl group of the amino acid dissociates to release a hydrogen ion. If the pH drops, the amino group accepts an additional hydrogen ion to form an NH_3^+ group. The plasma proteins contribute to the buffering capabilities of the blood; inside cells the protein buffer systems stabilize the pH of the ECF by absorbing extracellular hydrogen ions or exchanging intracellular hydrogen ions for extracellular potassium. (2) Carbonic acid-bicarbonate system- most carbon dioxide generated in tissues is converted to carbonic acid, which dissociates into a hydrogen ion and a bicarbonate ion. Hydrogen ions released by dissociation of organic or fixed acids combine with bicarbonate ions, elevating the P_{CO2};

additional CO_2 is lost at the lungs. (3) Phosphate buffer systems - the phosphate buffer system consists of a weak acid, $H_2PO_4^-$, a weak acid, that in solution reversibly dissociates into a hydrogen ion and HPO_4^{2-}. The phosphate buffer system plays a relatively small role in regulating the pH of the ECF, because the ECF contains far higher concentrations of bicarbonate ions than phosphate ions; however, it is important in buffering the pH of the ICF.

49. Secreting or absorbing hydrogen ions; controlling the excretion of acids and bases; generating additional buffers

50. Respiratory compensation is a change in the respiratory rate that helps stabilize the pH of the ECF. Increasing or decreasing the rate of respiration alters pH by lowering or raising the P_{CO2}. When the P_{CO2} goes down, the pH rises; when the P_{CO2} increases, the pH decreases. Renal compensation is a change in the rates of hydrogen and bicarbonate ion secretion or reabsorption in response to changes in plasma pH. Tubular hydrogen ion secretion results in the diffusion of bicarbonate ions into the ECF.

51. Respiratory disorders result from abnormal carbon dioxide levels in the ECF. An imbalance exists between the rate of CO_2 removal at the lungs and its generation in other tissues. Metabolic disorders are caused by the generation of organic or fixed acids or by conditions affecting the concentration of bicarbonate ions in the ECF.

52. Alkalosis refers to a rise in the pH of body fluids. Respiratory alkalosis (hypocapnia) results from an abnormally low level of carbon dioxide, usually caused by hyperventilation. Metabolic alkalosis occurs when bicarbonate ion levels rise and the bicarbonate ions interact with hydrogen ions to form carbonic acid. It can result from episodes of prolonged vomiting when stomach acids are being generated, causing the ECF bicarbonate concentration to rise.

53. (a) Excessive sodium and water intake causes an increase in total blood volume and blood pressure. Increased blood pressure results in decreased ADH secretion and reduced renin secretion from the kidneys. Decreased renin results in decreased production of angiotensin II, which reduces the rate at which aldosterone is secreted. Increased sodium ions and increased blood pressure cause the secretion of atrial natriuretic peptide, inhibiting ADH secretion and sodium ion reabsorption in the DCT. These changes cause increased loss of sodium in the urine and an increase in the volume of urine produced. (b) If the amount of salt ingested is excessive, the urine volume will be larger and the concentration of salt in the urine will be high. If the amount of water is excessive, the urine volume will be increased, and the concentration of sodium ions in the urine will be decreased. (c) If the amount of salt and water ingested in food exceeds the amount needed to maintain a constant ECF composition, it increases the total blood volume and increases the blood pressure.

54. Since sweat is usually hypotonic, the loss of a large volume of sweat causes hypertonicity in body fluids. The loss of fluid volume is primarily from the interstitial space, which leads to a reduction in plasma volume and an increase in the hematocrit. Severe dehydration can cause the blood viscosity to increase substantially, resulting in an increased work-load on the heart, ultimately increasing the probability of heart failure.

Level 3: Critical Thinking/Application

55. The young boy is suffering from metabolic and respiratory acidosis. Sustained hypoventilation during drowning leads to decreased arterial PO_2, and oxygen-starved tissues generate large quantities of lactic acid. Prompt emergency treatment is essential, and the usual procedure involves some form of artificial or mechanical respiratory assistance coupled with the intravenous infusion of an isotonic solution containing sodium lactate, sodium gluconate, or sodium bicarbonate.

56. The patient is most likely suffering from acidosis. The disorientation could be the result of decreased pH in the ICF of the brain. The hyperventilation would be a response to acidosis, since hyperventilation removes carbon dioxide, the source of a volatile acid, carbonic acid. Finally, in acidosis, hydrogen ions move into the ICF and potassium ions move out in exchange. This coupled with increased potassium ion retention at the kidney due to increased hydrogen ion excretion could account for the hyperkalemia.

57. As long as the ratio of bicarbonate ion to carbonic acid in the blood is 20:1, the pH of the blood will be 7.4. If the bicarbonate is significantly elevated without a change in pH, then the concentration of carbon dioxide and carbonic acid in the blood must also be increased. This is consistent with emphysema. Patients suffering from emphysema have lost surface area and ventilation capacity and are not able to efficiently clear the carbon dioxide from the blood. The result is a chronic elevation in the level of carbon dioxide and carbonic acid. In order to maintain homeostasis, the body makes adjustments, primarily at the kidneys, to raise the bicarbonate level appropriately to keep the pH in the normal range.

58. Digestive secretions contain high levels of bicarbonate, therefore persons suffering from diarrhea can lose significant amounts of this important ion, leading to acidosis. We would expect Milly's blood pH to be lower than 7.4, and the pH of her urine also to be low (due to increased renal excretion of hydrogen ion). We would also expect an increase in the rate and depth of breathing as the respiratory system tries to compensate by eliminating carbon dioxide.

59. The hypertonic solution will cause fluid to move from the ICF to the ECF, further aggravating Yuka's dehydration. The slight increase in pressure and osmolality of the blood should lead to an increase in ADH, although ADH levels are probably quite high already. Urine volume would probably increase, since much of the glucose would not be reabsorbed. This would increase the osmolality of the tubular filtrate, decreasing water reabsorption and increasing urine volume.

60. Patient 1 has compensated respiratory alkalosis. Patient 2 has acute metabolic acidosis due to generation or retention of organic or fixed acids. Patient 3 has acute respiratory acidosis. Patient 4 has metabolic alkalosis.

❑ Media Lab Instructor Notes

Web addresses often change. To avoid dead links, we are listing the keywords in parentheses next the to Web Explorations. Simply go to the Companion Website (http://www.prenhall.com/martini), select the Fifth Edition of Fundamentals of Anatomy and Physiology and search using the key word to locate the current address.

Animations (Website)

- Figure 27-3—Animation in play / next format. Fluid Exchanges; suitable for lecture demonstration of compartmental fluid movement or self-study.
- Figure 27-5—Animation in play / next format. The integration of fluid volume regulation and sodium ion concentrations in body fluids; suitable for lecture demonstration of homeostatic fluid regulation or self-study after presentation.
- Figure 27-6—Animation in play / next format. Basic relationship between PCO2 and plasma pH; suitable for lecture demonstration of pH and ion concentrations (general mechanism) or self-study tool after presentation.

Web Explorations (Overview)
Web Exploration 1 (**DEHYDRATION**)

- *Goal*—review, application of knowledge
- *Description of page*—Heat and Hydration course from Rice University
- *Expectations of student behavior*—read information, move to self-test, write inferences
- *Instructor's role*—guide thought processes during interpretation, explain heat stroke
- *Special notes or further uses of exploration*—"back to home" link provides pages in hyponatremia, glycerol and hydration—good for further study.

Web Exploration 2 (**REHYDRATION**)

- *Goal*—critical thinking, information application
- *Description of page*—Portable Emergency Physician Information Database (commercial site)
- *Expectations of student behavior*—compare solution composition using text, write and discuss ion functions
- *Instructor's role*—provide guidance on ion functions within the body, assist in critical thinking
- *Special notes or further uses of exploration*—not terribly helpful resource; very clinical page links

Additional Web Explorations
Should the two explorations found in the text not answer your needs, a third exploration is provided below. Your students do not have direct access to this exploration. You must provide them the address and information in the following paragraph.

Web Exploration 3
Estimated time for completion = 5 minutes

Hemodialysis is the process of cleansing the blood using the properties of diffusion across a semipermeable membrane. Renal replacement therapies are constantly advancing. The latest advancement is referred to as CVVH. To read about the **CVVH** procedure, go to the web address (http://pedsccm.wustl.edu/All-Net/english/kidpage/CVVH/intro.html). As you read through this article, prepare a concept map of how CVVH works. Include a comparison of CVVH to older methods. When is CVVH recommended?

Web Exploration 3 (**CVVH**)

- *Goal*—knowledge application, current events
- *Description of page*—All-Net Pediatric Critical Care page, including links to research, conferences and other pediatric care information
- *Expectations of student behavior*—read, prepare outline
- *Instructor's role*—thoroughly explain ion movement in hemodialysis, assist in constructing concept map, keep students on track with links
- *Special notes or further uses of exploration*—"several advantages" link helpful explanation of general hemodialysis; "replacement fluid" link explains ion concentration of fluid

Objectives	TOPIC OUTLINE **Chapter 27** **Fluid, Electrolyte, and Acid-Base Balance** (page 1 of 3)	Figures	Strategies	A/V RESOURCES: Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	I. Introduction							
1a	**II. Fluid Balance and Electrolyte Balance**	27-1,2	1a, 6a	●	●			
2a	A. Basic Concepts in the Regulation of Fluids and Electrolytes							
2b	B. An Overview of the Primary Regulatory Hormones	21-17,18 26-10	6b	●	●			
	1. Antidiuretic Hormone							
	2. Aldosterone	26-13a		●	●			
	3. Atrial Natriuretic Peptide							
	C. The Interplay Between Fluid Balance and Electrolyte Balance		1b					
	D. Fluid Balance	27-3		●	●	●		
	1. Fluid Movement within the ECF	21-13		●	●			
	2. Fluid Exchange with the Environment	27-3		●	●			
2c	3. Fluid Shifts	3-8		●	●			

Topic Outline				A/V Resources				
Objectives	**Chapter 27** **Fluid, Electrolyte, and Acid-Base Balance** (page 2 of 3)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	E. Electrolyte Balance		5a					
	1. Sodium Balance	27-4,5		●	●	●		●
	2. Potassium Balance	26-14c		●	●	●		
	3. Other Electrolytes							
	III. Acid-Base Balance		5b					
	A. The Importance of pH Control							
	B. Types of Acids in the Body	27-6		●	●	●		
	C. Mechanisms of pH Control	27-7		●	●			
	1. Protein Buffer Systems	23-25, 27-8		●	●			
	2. The Carbonic Acid-Bicarbonate Buffer System	26-14c 27-9		●	●			
	3. The Phosphate Buffer System							
3b	D. Maintenance of Acid-Base Balance							
	1. Respiratory Compensation	23- 27,28		●	●			
	2. Renal Compensation	26-12,14, 27-10	6e	●	●			

TOPIC OUTLINE				A/V RESOURCES				
Objectives	**Chapter 27** **Fluid, Electrolyte, and Acid-Base Balance** (page 3 of 3)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
4a	**IV. Disturbances of Acid-Base Balance**	27-11	6f	●	●			
	A. Respiratory Acidosis	27-12a		●	●			
	B. Respiratory Alkalosis	27-12b		●	●			
	C. Metabolic Acidosis	10-18, 27-13		●	●			
	1. Combined Respiratory and Metabolic Acidosis							
	D. Metabolic Alkalosis	27-14		●	●			
	E. The Detection of Acidosis and Alkalosis							
	V. Aging and Fluid, Electrolyte, and Acid-Base Balance							

CHAPTER 28

The Reproductive System

Introduction

An interesting pair of topics to introduce students to this chapter are breast and testicular cancer (a little something for everyone). Both types of cancer are common. The recent discovery of a susceptibility gene for breast cancer (BRCA1) allows for early screening this type of cancer. The genetic testing for breast cancer is discussed in a recent article by Barbara Weber (*Scientific American Science and Medicine*, January/February 1996). Some of the problems associated with treatment choice if mutated BRAC1 is found are discussed. The exact normal function of this gene is not known but it appears to be a member of the tumor suppressor family. Testicular cancer is an example of a relative success story in cancer research. This type of cancer is now essentially curable. The molecular and cellular mechanisms involved in production of the cancer are still under active research. The article "Testicular Cancer" by Ivan Damjonov (*Scientific American Science and Medicine*, January/February 1995) is a good introduction to this subject.

Instructional Goals/Learning Objectives

1. To describe the histological and functional characteristics of the male and female reproductive tracts.

   a. *Summarize the functions of the human reproductive system and its principal components.*
   b. *Describe the components of the male reproductive system.*
   c. *Detail the processes of meiosis, spermatogenesis, and spermiogenesis.*
   d. *Describe the roles the male reproductive tract and the accesssory glands play in the functional maturation, nourishment, storage, and transport of spermatozoa.*
   e. *Discuss the normal composition of semen.*
   f. *Describe the male external genitalia.*
   g. *Describe the hormonal mechanisms that regulate male reproductive functions.*
   h. *Describe the components of the female reproductive system.*
   i. *Detail the processes of meiosis and oogenesis in the ovary.*
   j. *Define the phases and events of the ovarian and uterine cycles.*
   k. *Describe the structure, histology, and functions of the vagina.*
   l. *Name and describe the parts of the female external genitalia and mammary glands.*
   m. *Describe the anatomical, physiological, and hormonal aspects of the female reproductive cycle.*
   n. *Discuss the physiology of sexual intercourse as it affects the reproductive systems of male and females.*
   o. *Describe the changes in the reproductive system occuring at puberty and with aging.*

2. To provide a background for the material in Chapter 29 concerning implantation and development.

❑ Teaching Strategies

1. Analogies

a. Compare the anatomical arrangement of the prostate to a donut whose hole is wrapped around a tube.

b. The description of the uterus as "pearshaped" has been used for so many years, that it reads as if it is one word: Pearshapeduterus. But when most students look at the pictures of the uterus, they don't see pear-shaped; they see "lightbulb!" (Perhaps if it were described as an upside-down pear, it would make more sense).

c. The fundus of the uterus and the fundus of the stomach are both rounded portions of a hollow organ positioned at a distance from the inlet.

d. Students (male and female) are always curious about the possibility of urine passing through the urethra during emission and ejaculation, though they are often too embarrassed to ask in the public forum of the classroom. To satisfy their curiosity and to help them avoid the embarrassment of asking, offer the following analogy. Compare the contraction of the sphincter muscle that closes off the opening to the bladder to the lifting of a drawbridge. Normal flow of traffic is permitted to proceed along the bridge as long as no other activity is competing for the water space beneath the bridge. As soon as a steamliner needs to pass, the stream of traffic is physically prevented from continuing because of the raising of the drawbridge. Once the steamliner has passed, the drawbridge is lowered and the flow of traffic returns to normal. It is a rather loose analogy, but the students love the puns.

2. Demonstrations

a. It might be less confusing to describe the generic processes of mitosis and meiosis (i.e., the four phases of mitosis as compared to MI and MII), and then go back and apply the process to spermatogenesis. It helps to make this explanation visual. Colored pipe cleaners make great chromosomes. Let shape represent homology, and color represent different expression of the homologous chromosome. Your table top is the cell. Starting with a simple example, manipulate the chromosomes to illustrate all the steps of the division processes. For example, use a cell that has the following pipe cleaner chromosomes: 1 long green, 1 long red, 1 short yellow, 1 short black (2n = 4). Emphasize that with mitosis, the goal is to end up with two cells, each genetically identical to the original cell. The goal of meiosis is to end up with four cells, each with half the number of chromosomes (2 pipe cleaners), AND each cell must have one of each of the representative homologs (1 long and 1 short). Start by asking the students, How many chromosomes does this cell have? (4). What is its diploid number? (4). What is its haploid number? (2). How many homologous pairs does it have? (2). Then demonstrate the replication process by giving each pipe

cleaner an identical mate. Ask the students again. How many chromosomes does this cell have? They will want to say eight, so emphasize the difference between a chromosome and a chromatid. Maneuver the pipe cleaners through mitosis first, describing each phase as you go. Then go back to the original cell, and demonstrate meiosis. Point out that during metaphase I, homologous pairs line up opposite each other (a contrast to the metaphase in mitosis). As soon as the cell has completed MI, it is haploid. All that remains is to separate sister chromatids during MII. Have the students work in groups performing the same task. You provide the diploid number and allow them to manipulate the pipe cleaners to represent both division processes. You can even show tetrad formation and crossing over with the pipe cleaners.

Once you are sure they have comprehended the process, go back and relate each step to spermatogenesis (spermatogonia, primary, secondary, spermatid). Use Figures 28-5 and 28-6 to demonstrate that the spermatogonia begin in the perimeter of the seminiferous tubule, but they get pushed toward the lumen as new spermatogonia form. As they are being pushed along, they continue the melotic process. By the time they arrive in the lumen, they are spermatids.

b. The ovaries in the female are analogous to the testes in the male. They are the site of mitosis and meiosis that eventually result in a gamete, the ovum. As you describe oogenesis, compare the terminology and meiotic divisions to spermatogenesis. At first glance the processes seem similar. Note that women are born with all the oogonia they will ever have, rather than continually producing new ones, as is the case with spermatogonia. Point out that, while the result of meiosis is four gametes in the male, the result in the female is only one gamete, and it does not complete the MII phase until after fertilization (no need to go through all that trouble for naught).

3. Vocabulary Aids

a. The condition cryptorchidism derives its name as follows. The word "orchid" comes from the Greek word element "orchio" and literally means testicle. The flowers get their name because of the structure of their root system. "Crypto," meaning hidden, is where we get the word "crypt," the place where we keep dead bodies "hidden."

b. Students tend to get all those "sperm" words mixed up: spermatogenesis, spermatogonia, spermiogenesis, spermatids, spermatocytes (can you blame them?). Try to clarify the terminology by introducing the process as a simple story. Explain that **spermatogenesis** is the whole, big picture process. As the word says: "To Create Sperm." The process begins with the **spermatogonia** or "sperm seed cells" (gonia is the Greek word for seed). These cells have to develop and multiply like any other kind of cell, through the process of mitosis. The result is a sperm seed cell that has become a full-blown sperm cell, the **spermatocyte**. Now, these spermatocytes are not ready to operate as sperm. First of all, they do not have the correct "little tadpole" structure. Second of all, they have 46 chromosomes. If their 46 chromosomes were to combine with 46 chromosomes in the egg during fertilization, we can only guess as to what a 96-chromosome baby would look like! This means that somehow the chromosome number has to be divided in half. 46x2=23 (a haploid gamete), 23 (sperm) + 23 (egg) = 46 (back to a diploid cell). The dividing-in-half process is called

meiosis, and the resulting haploid gamete is the **spermatid**. You can remember this, because the word spermatid sounds only half as long as the word spermatocyte. But the story isn't over. Little, baby spermatids have to grow into big, strong mature **spermatozoa**, a process known as **spermiogenesis**.

c. If the students have become used to associating the word "os" with "bone," the use of it to describe the openings of the cervical canal may be puzzling. Mention that the word os can mean "mouth."

4. Applications

a. The cremaster muscle is a continuation from the abdominal muscles.

b. During a physical examination, the prostate gland is palpated through the wall of the rectum. Refer the students back to Figure 28-1, so that they can see the spacial relationship between the prostate gland and the rectum.

c. Indicate that the fimbriae drape themselves over the surface of the ovary, but the ovary and uterine tube are not physically connected, a fact that makes women susceptible to PID, since there is no physical barrier to prevent outside "stuff" from getting inside.

d. The normal acidic environment of the vagina is a protective mechanism against pathogens, but it is also incompatible with sperm survival. The alkaline secretions of semen make the vaginal environment more "user friendly."

e. It is the surgical removal of the clitoral hood or prepuce (female circumcision) that is practiced by some Islamic cultures.

f. Sexual function is an example of sympathetic and parasympathetic dual innervation that provides cooperative control rather than the usual antagonistic control.

g. The menstrual periods can become so erratic during the time prior to menopause, that determining when they have ceased can be questionable. For this reason, a woman is usually not considered to be menopausal until ovulation and menstruation have stopped for one year.

5. Common Student Misconceptions/Problems

a. Students know that there are two testicles, but they (particularly females) may not be aware that these are contained within a single pouch.

b. A sagittal section through the penis can be deceiving to the students, because it gives them the impression that there is only one corpus cavernosum. Make sure to clarify using sagittal, frontal, and cross sectional views.

c. It sometimes confuses students to find out that there is FSH in males. They assume that since the F stands for follicle, that the hormone can only be in females,

controlling the development of the follicles in the ovary. Point out that the hormone

is released from the anterior pituitary in BOTH males and females, and it has a similar effect in both sexes in that it helps to initiate the development of the gamete.

d. Many textbooks use a composite drawing of the ovary, showing all the stages in one ovary at one time. While the decision to represent the ovary in that manner is probably one of space availability, the result is misleading for the students. Their perception is that all those things are in the ovary all the time. The misconception persists, even if there is an attempt made by the author to designate a temporal relationship. Figure 28-15 solves that problem by showing sequenced drawings and micrographs of the ovary as it progresses through the ovarian cycle.

As the students examine Figure 28-15, point out that the appearance of the ovary is constantly changing depending upon the hormonal control of follicular development, ovulation, and the corpus luteal stage. Trying to understand the condition of the ovary from one drawing is like trying to figure out how the butterfly stroke is performed in swimming by examining a single snapshot of a swimmer. A single snapshot only reveals what the swimmer looks like at the instant the picture was taken. The only way to know what he looked like the instant before or the instant after is to take lots of snapshots (or a video). In the absence of a video of the ovary, the next best thing is to examine the ovary in progressive drawings. It never looks the same from one time of the month to another. As a result histological examination of the ovary can be very revealing as to what time period in the ovarian cycle was occurring during the preparation of the tissue. Obviously, if there is a mature Graafian follicle present, there will be an absence of a corpus luteum (and vice versa). Hence, by looking at the mature Graafian follicle stage (Figure 28-15), we can assume that the "snapshot" of that ovary was taken on, or about, day 12 of the ovarian cycle (Figure 28-24). Since each picture represents a specific time of the ovarian cycle, a single snapshot can tell a story about what is going on in other organs all affected by the hormonal regulation of the entire reproductive cycle.

e. If the menstrual cycle is truly a cycle, then it does not have a beginning or an end, but most students think of menses as the end of the cycle rather than the beginning. Stress that traditionally, "Day 1" occurs with the onset of menses.

6. Lecture ideas

a. Most students are amazed that the testes form inside the abdominal cavity. Explain that the descent is necessary, since the sperm cannot survive at temperatures as high as the body's. By growing downward and outward through the inguinal canal, they end up outside the body cavity and remain 2-3 degrees below body temperature. As the testes descend, they take all their blood, nerve, and ductile connections (the spermatic cord), as well as an invaginated part of the parietal peritoneum that becomes the vaginalis. Clarify that testicle descent does NOT include the scrotum. The scrotum develops as, and remains strictly, an external structure.

b. Point out that the epididymis is coiled along the outside of the testicle the way the seminiferous tube was coiled within the compartments inside the testis.

c. Point out that the glans is the external extension of the internal corpus spongiosum.

d. Since the ovum is the "star" of the reproductive cycle, all activity truly revolves around it. Making the ovum the center of attention, as it were, helps make sense of the pattern of hormonal activity leading up to its release and the hormonal patterns following its release. From the point of view of the reproductive system, it must spend half its energy getting the egg ready and releasing it, and the rest of its energy preparing for the likelihood of fertilization. As you organize the discussion of the hormonal controls based upon pre and post ovulatory activity, try to add logic to the activities that you will be describing, as opposed to just presenting a chronological list of events.

e. For the first time, in this edition I decided to cover the current understanding of female reproductive physiology and the regulatory mechanisms involved. The interactions among the various hormones involved are complex and still incompletely understood, but the basic patterns are generally accepted. This is a fascinating research area, and we will no doubt learn more during the life of this edition. (Keep an eye on the website for updates.) The major uncertainties, in case you are asked, include the following (From Ric Martini):

   i. It is not possible, due to the short half-life of GnRH (a couple of minutes) to monitor the amplitude. It is therefore tough to determine how large and how important changes in amplitude really are. It does seem that amplitude changes have a function, and that the function is more complex than the known functions of changing pulse frequency. For example, during the follicular phase the amplitude decreases as the frequency rises, but in the luteal phase the amplitude goes lo-lo-hi-lo-hi-lo-lo-lo-hi-hi etcetera. What message is conveyed and how it is received remains unclear; that is why I chose to focus on the frequency changes in this discussion.

   ii. Although some researchers have suggested that the GnRH pulse frequency changes at the time of the LH surge, based on work with other mammals, other investigators maintain that in primates it remains stable, and neither changes in the pulse frequency nor amplitude can be solidly linked to the LH peak. The problem is that you cannot cannulate the hypophyseal portal in women, and it is impossible to determine whether the effects you can monitor, such as LH output, actually represent a gonadotrope response to (1) increased GnRH secretion, (2) increased pulse frequency without a change in amplitude, or (3) increased sensitivity of the gonadotropes to GnRH at a stable background level and frequency. I believe that the evidence favors a stable GnRH plateau accompanied by increased estrogen-induced LH-cell sensitivity that triggers the surge.

   iii. The mechanism of FSH vs LH transcription, translation, and secretion may be independently regulated. Low GnRH frequencies at the start of the follicular

phase stimulate LH transcription more than FSH, but favor FSH secretion more than LH. At the end of the luteal phase, there is a storehouse of FSH in the gonadotropes, so when GnRH frequencies rise, FSH output increases well ahead of LH output.

❑ Answers to End of Chapter Exercises

Level 1: Reviewing Facts and Terms

1. c
2. d
3. d
4. c
5. a
6. c
7. a
8. d
9. d
10. c
11. a
12. c
13. c
14. d
15. d
16. b
17. a
18. c
19. b
20. a
21. d

22. The reproductive system of males and females includes: reproductive organs (gonads) that produce gametes and hormones; ducts that receive and transport gametes; accessory glands and organs that secrete fluids into these or other excretory ducts; perineal structures collectively known as external genitalia

23. Seminiferous tubules ⇒ rete testis ⇒ efferent ducts ⇒ epididymis ⇒ ductus (vas) deferens ⇒ ejaculatory duct ⇒ urethra.

24. The accessory organs/glands include the seminal vesicles, prostate gland and the bulbourethral glands. The major functions of these glands are: activating the spermatozoa, providing the nutrients sperm need for motility, propelling sperm and fluids along the reproductive tract, producing buffers that counteract the acidity of the urethral and vaginal contents.

25. The interstitial cells (cells of Leydig) are responsible for the production of male sex hormones (androgens), the most important one being testosterone. The sustentacular cells (Sertoli cells) have six important functions:
    a) maintenance of the blood testis barrier
    b) support of spermatogenesis
    c) support of spermiogenesis
    d) secretion of inhibin
    e) secretion of androgen-binding protein
    f) secretion of Mullerian-inhibiting substance

26. (1) It monitors and adjusts the composition of the tubular fluid.
    (2) It acts as a recycling center for damaged spermatozoa.
    (3) It stores spermatozoa and facilitates their functional maturation.

27. (a) prostatic urethra (b) membranous urethra (c) penile urethra

28. A typical sample of ejaculate contains: spermatozoa - normal count is 20-100 million/ml; seminal fluid - fluid component of semen, a mixture of glandular secretions with distinctive ionic and nutrient composition; enzymes - a protease that may help to dissolve mucous secretions in the vagina and seminal plasmin, an antibiotic enzyme that kills a variety of bacteria.

29. Stimulates spermatogenesis and promotes the functional maturation of spermatozoa. Maintains the male reproductive accessory organs. Determines male secondary sex characteristics. Stimulates metabolic operations, especially those concerned with protein synthesis and muscle growth. Influences brain development by stimulating sexual behaviors and sexual drive.

30. The production and release of female gametes (ova). The secretion of female sex hormones, including estrogens and progestins. The secretion of inhibin, involved in the feedback control of pituitary FSH production.

31. Step 1: formation of primary follicles
Step 2: formation of secondary follicles
Step 3: formation of a tertiary follicle
Step 4: ovulation
Step 5: formation and degeneration of the corpus luteum

32. Myometrium - outer muscular layer
Endometrium - inner glandular layer
Perimetrium - incomplete serosal layer

33. (1) The vagina serves as a passageway for the elimination of menstrual fluids. (2) The vagina receives the penis during sexual intercourse and holds spermatozoa prior to their passage into the uterus. (3) In childbirth, the vagina forms the lower portion of the birth canal through which the fetus passes during delivery.

34. The acids, which are secreted by bacteria, inhibit the growth of many pathogens.

35. The clitoris is a structural component of the external genitalia of the female. Anterior to the urethral opening, it projects into the vestibule. The clitoris is the female equivalent of the penis, derived from the same embryonic structures. Internally the clitoris contains erectile tissue comparable to the corpus spongiosum of the penis. The clitoris becomes engorged with blood during sexual arousal.

36. The lesser vestibular glands discharge their secretions onto the exposed surface of the vestibule, keeping it moistened. During arousal a pair of ducts discharges the secretions of the greater vestibular glands into the vestibule near the posterolateral margins of the vaginal entrance.

37. Glandular tissue (lobes) - contains secretory lobules ⇒ ducts ⇒ lactiferous duct ⇒ lactiferous sinus ⇒ open onto the surface of each nipple.

Level 2: Reviewing Concepts

38. The reproductive system is the only physiological system that isn't required for survival of the individual.

39. In males, the gonads (testes) secrete androgens and produce one-half billion gametes (sperm) each day. The sperm are mixed with secretions, forming semen, are expelled

from the body during ejaculation. In females, the gonads (ovaries) secrete estrogen and progesterone, and release one ovum (gamete) every month. The ovum may be fertilized within the oviduct.

40. Meiosis is the two-step nuclear division resulting in four haploid cells from one diploid cell. In males, four sperm are produced from each diploid cell. In females only one ovum (plus three polar bodies) is produced from each diploid precursor.

41. The corpora cavernosa extend along the length of the penis as far as the neck of the penis, and the erectile tissue within each corpus cavernosum surrounds a central artery. The slender corpus spongiosum surrounds the urethra. This erectile body extends from the superficial fascia of the urogenital diaphragm to the tip of the penis, where it expands to form the glans. The sheath surrounding the corpus spongiosum contains more elastic fibers than do the corpora cavernosa, and the erectile tissue contains a pair of arteries. Erection occurs when the parasympathetic neurons of the penile arteries release nitric oxide, causing the smooth muscles in the arterial walls to relax. When this occurs: the vessels dilate, blood flow increases, the vascular channels become engorged with blood, and erection of the penis occurs.

42. (1) Menses - period marked by the degeneration and loss of the functional zone of the endometrium. Usually lasts from 1-7 days and over this period approximately 35-50 ml of blood are lost. (2) Proliferative phase - Growth and vascularization during this phase result in the complete restoration of the functional zone. This preovulatory or follicular phase lasts from the end of the menses until the beginning of ovulation around day 14. (3) Secretory phase - the endometrial glands enlarge, accelerating their rates of secretion and the arteries elongate and spiral through the tissues of the functional zone. This activity occurs under the combined stimulatory effects of progestins and estrogens from the corpus luteum. This phase begins at the time of ovulation and persists as long as the corpus luteum remains intact.

43. As follicular development proceeds, the concentration of circulating estrogen rises. Secondary follicles contain increased numbers of granulosa cells, and the level of circulating inhibin rises. The rising estrogen and inhibin levels inhibit hypothalamic secretion of GnRH and pituitary production and release of FSH. As the follicles develop and estrogen levels rise, the pituitary output of LH gradually increases. Estrogens, FSH, and LH continue to support follicular development and maturation despite a gradual decline in FSH levels. Second week of ovarian cycle- sharp increase in estrogen concentrations - tertiary follicle enlarges in preparation for ovulation. Day 14 - estrogen levels peak, triggers a massive outpouring of LH from the anterior pituitary. The rupture of the follicular wall results in ovulation. After ovulation - LH stimulates formation of the corpus luteum, which secretes moderate amounts of estrogens, but great amounts of progesterone, the principal hormone of the postovulatory period. About 12 days after ovulation declining progesterone and estrogen levels stimulates hypothalamic receptors and GnRH production increases, leading to increased FSH and LH production in the anterior pituitary, causing the entire cycle to begin again.

44. Corpus luteum degeneration- decline in progesterone and estrogen levels, results in endometrial breakdown of menses. After menses, rising levels of FSH, LH and estrogen

stimulate repair and regeneration of functional zone of endometrium. During the postovulatory phase the combination of estrogen and progesterone cause the enlargement of the endometrial glands and an increase in their secretory activity.

45. During arousal, erotic thoughts or physical stimulation of sensory nerves in the genital region increases the parasympathetic outflow over the pelvic nerve, leading to erection of the clitoris or penis. Orgasm is the intensely pleasurable sensation associated with perineal muscle contraction and ejaculation in the male, and with uterine and vaginal contractions and perineal muscle contraction in the female. These processes are comparable in the two sexes.

46. Women age 45-55 undergo menopause, the time that ovulation and menstruation ceases. Menopause is accompanied by a sharp and sustained rise in the production of GnRH, FSH and LH, while concentrations of circulating estrogen and progesterone decline. The decline in estrogen levels leads to reductions in the size of the uterus and breasts, accompanied by a thinning of the urethral and vaginal walls. In addition to a variety of neural and cardiovascular effects, reduced estrogen concentrations have been linked to development of osteoporosis, presumably because bone deposition proceeds at a slower rate. During the male climacteric, circulating testosterone levels begin to decline between ages 50 and 60+, coupled with increases in circulating levels of FSH and LH. Although sperm production continues, there is a gradual reduction in sexual activity in older men.

47. Birth control pills contain progestins and estrogens (hormones), which are administered in a cyclic fashion, beginning five days after the start of menses and continuing for the next three weeks. Over the fourth week, placebo pills or no pills at all are taken. The slightly elevated levels of progestin and estrogen inhibit GnRH release at the hypothalamus and the release of FSH and LH from the anterior pituitary. Without FSH primordial follicles do not initiate development and an LH surge is necessary for ovulation to occur. Although the ovarian cycle is interrupted by the birth control pill, the level of hormone is still adequate to regulate a normal menstrual cycle if the "right" pill is prescribed.

Level 3: Critical Thinking/Clinical Application

48. There is no direct entry into the abdominopelvic cavity in males as there is in females. In females, the urethral opening is in close proximity to the vaginal orifice, therefore, infectious organisms can exit from the urethral meatus and enter the vagina. They can then proceed through the vagina to the uterus, then into the uterine tubes and finally into the peritoneal cavity.

49. The sacral region of the spinal cord contains the parasympathetic centers that control the genitals. Damage to this area of the spinal cord would certainly interfere with achieving an erection by way of parasympathetic stimuli. However, erection can also occur by way of sympathetic centers in the lower thoracic region of the cord. Visual, auditory, or cerebral stimuli can result in decreased tone in the arteries serving the penis. This results in increased blood flow and erection. Tactile stimulation of the penis, however, would not generate an erection.

50. Granulosa cells produce estrogens. A tumor involving these cells would lead to elevated levels of estrogens similar to or higher than those of an adult female. We would expect to observe the development of secondary sex characters, in response to the elevated levels of estrogens.

51. Ovarian thecal cells and granulosa cells depend on androgens as a substrate for production of female hormones. Blocking the testosterone producing enzyme, would decrease the available substrate for estrogens and progesterone, and levels of these hormones would decline. Without proper estrogen levels, follicles would not develop properly and ovulation would not occur.

52. It suggests that a certain amount of body fat is necessary for menstrual cycles to occur. The nervous system appears to respond to circulating levels of the hormone leptin; when leptin levels fall below a certain set point, menstruation ceases. Without proper fat reserves, a woman might not be able to have a successful pregnancy. To avoid harm to the mother and the death of a fetus, the body prevents pregnancy by shutting down the ovarian cycle and thus the menstrual cycle. When appropriate energy reserves are available, the cycles begin again.

❑ Media Lab Instructor Notes

Web addresses often change. To avoid dead links, we are listing the keywords in parentheses next the to Web Explorations. Simply go to the Companion Website (http://www.prenhall.com/martini), select the Fifth Edition of Fundamentals of Anatomy and Physiology and search using the key word to locate the current address.

Animations (Website)

- Figure 28- 5—Animation in play / pause format. The seminiferous tubules; suitable for lecture demonstration of sperm formation or self-study.
- Figure 28- 16—Animation in play / next format. The ovarian cycle; suitable for lecture demonstration of oocyte development or self-study.
- Figure 28- 26—Animation in play / next format. Hormonal regulation of the female reproductive cycle; suitable for lecture demonstration of female reproductive cycle integration or self-study tool after presentation.
-

Animations (CD-ROM)

- Rotating 3-dimensional image of male reproductive system corresponding to Figure 28-1 The male reproductive system.
- Rotating 3-dimensional image of female reproductive system corresponding to Figure 28-13 The female reproductive system.

Web Explorations (Overview)
<u>Web Exploration 1</u> (**REPRODUCTION QUIZ**)

- *Goal*—review, drill and practice
- *Description of page*—Biology Project University of Arizona
- *Expectations of student behavior*—read questions, click answer or tutorial, create study sheet
- *Instructor's role*—present reproductive system information first, help in creation of study sheet
- *Special notes or further uses of exploration*—"Biology Project" link provides resources for studies in biochemistry, cell biology, immunology, Mendelian genetics and molecular biology.

<u>Web Exploration 2</u> (**IMPOTENCE**)

- *Goal*—review, application of information
- *Description of page*—Andrology commercial site with left side bar links and top / bottom links
- *Expectations of student behavior*—read information, organize information in pamphlet form
- *Instructor's role*—discuss impotence and male reproductive physiology, maintain student focus on pamphlet
- *Special notes or further uses of exploration*—many links on male reproductive health

Additional Web Explorations
Should the two explorations found in the text not answer your needs, a third exploration is provided below. Your students do not have direct access to this exploration. You must provide them the address and information in the following paragraph.

Web Exploration 3
Estimated time for completion = 5 minutes

Perhaps you have heard of the phenomenon of menstrual synchrony in herd animals. This same phenomenon is known to occur in human females living in close proximity to one another. Dr. Martha McClintock has studied this **MENSTRUAL SYNCHRONY**, looking for pheromones that may be responsible. To read an interview with Dr. McClintock on her findings, go to the web address (http://www.abc.net.au/rn/talks/8.30/helthrpt/stories/s11122.htm). Read about her research and her thoughts on the results. What do you think causes this phenomenon? Discuss your ideas with your classmates using the communication applications found on the Companion Website.

Web Exploration 3 (**MENSTRUAL SYNCHRONY**)

- *Goal*—critical thinking, knowledge application
- *Description of page*—Radio National Health report interview with Norman Swain and Dr. McClintock
- *Expectations of student behavior*—read, prepare outline, discuss implications
- *Instructor's role*—explain female hormone cycle, discuss pheromone research, guide discussion
- *Special notes or further uses of exploration*—bottom of interview lists McClintock's papers; links at end to other radio interviews (further studies with current researchers)

Topic Outline				A/V Resources				
Objectives	**Chapter 28** **The Reproductive System** (page 1 of 4)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	I. Introduction							
1a	**II. An Overview of the Reproductive System**	8-8,10, 11-13 31-11, 21-28,34		●	●			
1b	**III. The Reproductive System of the Male**	28-1		●	●	●		●
	A. The Testes		6a					
	1. Descent of the Testes	28-3		●	●			
	2. The Spermatic Cords	28-2a	3a	●	●			
	3. The Scrotum and the Position of the Testes	28-3	4a, 5a	●	●			
	4. The Structure of the Testes	28-4		●	●			
	5. Histology of the Testes	28-4,5	2a, 3b	●	●			
1c	6. Spermatogenesis	28-6,7		●	●	●		
	B. The Anatomy of a Spermatozoon	28-8		●	●		●	●
1d	C. The Male Reproductive Tract		6b					
	1. The Epididymus	28-4,9		●	●			
	2. The Ductus Deferens	28-1,3,9a,10b		●	●			

Topic Outline				A/V Resources				
Objectives	**Chapter 28** **The Reproductive System** (page 2 of 4)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	3. The Urethra	28-1		●	●			●
	D. The Accessory Glands							●
	1. The Seminal Vesicles	28-10ac,11a		●	●			
	2. The Prostate Gland	28-10ad,11a		●	●			
	3. The Bulbourethral Gland	28-10e,11a	1a, 4b	●	●			
1e	E. Semen							
1f	F. The Penis	28-11	5b, 6c	●	●			
1g	G. Hormones and Male Reproductive Function	28-12		●	●			
	1. FSH and Spermatogenesis							
	2. LH and Androgen Production							
1h	**IV. The Reproductive System of the Female**	28-13		●	●	●		●
	A. The Ovaries	28-14,15		●	●			●
1i	1. Oogenesis	28-16	1b	●	●		●	●
1j	2. The Ovarian Cycle	28-16	5d	●	●	●		

TOPIC OUTLINE				A/V RESOURCES				
Objectives	**Chapter 28 The Reproductive System** (page 3 of 4)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	3. Age and Oogenesis							
	B. The Uterine Tubes	28-13,14,17	4c	●	●			
	1. Histology of the Uterine Tube	28-17bc			●			
	C. The Uterus	28-13	1b	●	●			
	1. Suspensory Ligaments of the Uterus	28-18ab		●	●			
	2. Internal Anatomy of the Uterus	28-18c	1c, 3c	●	●			●
	3. The Uterine Wall	28-18c,19		●	●			●
	4. The Uterine Cycle	28-20	5e	●	●			
1k	D. The Vagina	28-22		●	●			
	1. Histology of the Vagina	28-21	4d	●	●			
1l	E. The External Genitalia	28-22	4e	●	●			
	F. The Mammary Glands	21-23, 28-23		●	●			
	G. Hormones and the Female Reproductive Cycle							
	1. Hormones and the Follicular Phase	28-24,25, 26[a-d]	6d	●	●	●		

Topic Outline				A/V Resources				
Objectives	**Chapter 28 The Reproductive System** (page 4 of 4)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
1m	2. Hormones and the Luteal Phase							
	3. Hormones and the Uterine Cycle	28-26cde		●	●	●		
	4. Hormones and Body Temperature	28-26f			●			
1n	**V. The Physiology of Sexual Intercourse**							
	A. Male Sexual Function	11-13	1d, 4f	●	●			
	B. Female Sexual Function							
1o	**VI. Aging and the Reproductive System**							
	A. Menopause		4g					
	B. The Male Climacteric							
	VII. Integration with Other Systems	28-27			●			

CHAPTER 29

Development and Inheritance

❑ Introduction

A major breakthrough occurred in the field of reproductive physiology last year. You should not miss the opportunity to point this out to your students. This is a wonderful chance to show them how alive and vibrant physiology still is. Last year, the mechanism of timing of human birth was finally worked out. Most of the textbook descriptions in the past have been based on the sheep model. It was known that the situation was different in humans, but it was this last year that the differences were finally understood. A good source of information on this topic is the article *The Timing of Birth*, by Roger Smith in the March 1999 issue of *Scientific American*. One practical application of this discovery is the development of a blood test that helps predict premature labor.

❑ Instructional Goals/Learning Objectives

1. To describe mechanisms of gamete formation and provide a review of gamete structure.

2. To introduce basic genetic principles and relate them to the inheritance of human traits.

3. To provide an overview of prenatal development, emphasizing the continuity of developmental events and the role of the placenta in supporting the developing fetus.

   a. *Explain how developmental processes are regulated.*
   b. *Describe the events of fertilization.*
   c. *List the three prenatal periods and describe the major events associated with each period.*
   d. *Explain how germ layers participate in the formation of extraembryonic membranes.*
   e. *Describe the role of the placenta as an endocrine organ.*
   f. *Describe the contributions of the maternal organ systems to the developing fetus.*
   g. *Discuss the structural and functional changes in the uterus during gestation.*

4. To summarize the process of labor and delivery and to consider common clinical problems associated with these events.

5. To emphasize the concept that postnatal development is a logical continuation of prenatal development.

   a. *Identify the features and functions associated with the various life stages.*

Teaching Strategies

1. Analogies

2. Demonstrations

a. If you plan to have the students do some Punnett Square diagrams for predicting inheritance, work through a demonstration problem. Students have more success with the working of such problems if they have been given a methodical pattern to follow. At first they may solve the genetic problems based on rote, mechanical manipulation, but as they work through more examples they will begin to see a pattern emerge. Put an example of a cross on the board, and go through each step, as if you were solving the prediction problem. Think out loud, so that the students can hear your thought process as you approach each step. Start by saying that the point of the procedure is to try to predict what genetic characteristics offspring will have, given the genes of the parents. One way to see the results of the genetic combination would be to let the individuals mate, wait around for the child to be born, and then examine it for the expression of the trait being considered. Of course this is neither practical, nor very accurate, since most genetic predictions are based upon more than one offspring.

1) Write the phenotype and the genotype of the cross.

2) Determine the possible alleles that each parent could contribute. This is the step that is frequently missed. Stress that the alleles are equivalent to haploid gametes, and that listing the alleles is just a way of predicting all the possible alleles that might exist. (Predicting is nothing more than looking at the possibilities or chances of something happening).

3) Develop the Punnett Square and fill in the results. Point out that the pairs of alleles within the square represent the possible offspring genotypes.

4) List the frequency of the genotype and phenotype. Explain that the frequency can be expressed as a percent or a ratio. Stress that the frequency is the same, no matter how many times the original parents mate.

3. Vocabulary Aids

a. The term "corona radiata" literally means rays of a crown.

b. Amphimixis translates as "both mixed together" or "a mixture of both."

c. Cesarean sections are named after Julius Caesar, who it is thought to have been born in such a manner.

d. When defining genotype and phenotype, indicate that the "genotype" denotes the "type of gene." The "PHenotype" denotes the "PHysical traits." Point out that their phenotypes are a direct result of their genotypes.

4. Applications

a. There is tremendous stress on a woman's body during pregnancy, as the various organ systems adapt to meet the needs of the pregnancy. These adaptations are why it is so important for women to get prenatal care, so that their blood pressure, nutritional state, and kidney functions can be monitored.

5. Common Student Misconceptions/Problems

a. The relevance of studying development and inheritance is not always obvious to the average anatomy & physiology student. He/she tends to think of it as simply a biological "subcategory" to real anatomy and physiology. Consequently, it may be worthwhile to spend a moment justifying your "reason for being" (and theirs), as it were. Point out that the knowledge gained about the organ systems and how they operate has a direct relationship to how those systems develop, from a time that goes back to even before they were systems, from the time they were a smile on the mother's face and a twinkle in the father's eye. Examples of the significance of development for the study of anatomy and physiology are numerous: tissues are categorized and all the organs of the organ systems differentiate according to the primary germ layers that form within 12 days of fertilization, the areas and ventricles of the brain are identified as a direct effect of neural tube development, tissue repair relies on many of the same mechanisms seen during the growing process, the digestive tract and folded serous membranes begin as an invagination in the blastocyst, and if nothing else can convince them, point out all the diseases that occur as a result of a malfunction of the developmental process. As one ponders the impact of development and inheritance on anatomy and physiology, the question comes to mind, "Why weren't these Chapters 1 and 2?"

b. Implantation, formation of the blastodisc, and especially gastrulation are extremely difficult for students to visualize. As the stages of implantation are described, have the students carefully examine Figures 29.3 and 29.4. Use additional drawings to enhance your description. Imagine the blastocyst "sinking into" the uterine lining the way you might sink into a big featherbed. The soft endometrium reaches up to envelope the blastocyst. Where they meet will become the placenta. For the blastodisc, imagine the two layers of cells sitting one on top of the other, like a blanket lying on top of you, completely covering you, head-to-toe. The blanket is the epiblast (epi: on top). You are the hypoblast (hypo: below). The bed below you represents the surface of the yolk sac as it touches the hypoblast cells. The air space above the blanket represents the amniotic cavity that touches the epiblast cells.

c. The process of gastrulation is difficult for students to visualize; they have trouble "seeing" how the epiblastic cells migrate toward the primitive streak and then invaginate. Describe the process as a folding over on "itself." Continue the bed analogy to help with the visualization process. "Okay, here's the situation. I have my blanket on top of me, but the side of the blanket that is touching my skin is rough-like itchy wool. The other side of the blanket, the side touching the amniotic space, is as smooth as silk. The more I lie there, the itchier the wool feels, until I can't stand it anymore. I decide that I need to pull at least some of the silky side in, so that it

touches me. The problem, however, is that the blanket is sewn to all four sides of the bed, so I can't untuck it to completely reverse it (don't ask how I got in there in the first place). If all I had with me under the covers was a pair of scissors (don't ask how I got those under there either), how could I get at least some of the silky side touching me, and do a minimum amount of damage to the blanket?" Actually, students who have had any sewing experience will probably be able to figure out rather quickly that all you need to do is make a long slit in the blanket, and fold some of the silky surface in on itself. Explain that the epiblast (blanket) and hypoblast (you) are still in the original positions, but part of the epiblast has invaginated along the primitive streak (slit cut with scissors), and turned itself to the inside, between the epiblast (which becomes the epiderm) and the hypoblast (which becomes the endoderm). This folded in portion becomes the mesoderm.

6. Lecture ideas

a. The cellular development and differentiation that occurs in the first trimester is crucial to the developmental steps that follow. These initial cells are the basis for the cells to come. If something happens to disturb their development, then the effect of that disruption is seen in every generation of cells that follows.

b. The chorionic villi hang in a pool of maternal blood, like gloved fingers in a pool of water. Each villus has a capillary bed to absorb nutrients, like the villi of the digestive tract, but it acts as the site for gas exchange as well. So the placenta is lung and digestive system rolled into one. Maternal blood bathes the villi, as it is carried to the placenta by maternal arteries, and carried away by maternal veins. Point out that two umbilical arteries bring the blood to the villi; one umbilical vein carries blood away from the villi. The vessels are named based upon the relationship they have to the embryo's heart, not the mother's heart.

❑ Answers to End of Chapter Exercises

Level 1: Reviewing Facts and Terms

1. a
2. b
3. d
4. b
5. b
6. d
7. a
8. b
9. c
10. c
11. b
12. a
13. a
14. d
15. a
16. b
17. d
18. c
19. d

20. When a sperm contacts the oocyte, their plasma membranes fuse. The oocyte is then activated: its metabolic rate rises, it completes meiosis II, and a cortical reaction occurs which prevents additional sperm from entering (vesicles beneath the oocyte surface fuse with the cell membrane and discharge their contents). The male and female nuclei fuse (amphimixis), and the zygote begins preparing for the first cleavage division.

21. Induction is the chemical interplay between developing cells. Some cells release chemical substances that affect the differentiation of other cells. The inductive process controls the differentiation of embryonic cells into specialized cells, a crucial part of human development.

22. During the first trimester the rudiments of all major organ systems appear. In the second trimester the organs and organ systems complete most of their development and the body proportions change to become more human. During the third trimester the fetus grows rapidly and most of the major organ systems become fully functional.

23. (a) (1) yolk sac; (2) amnion; (3) allantois: and (4) chorion (b) The yolk sac forms from the endoderm and mesoderm; it is an important site of blood cell formation. The amnion forms from ectoderm and mesoderm; it encloses fluid that surrounds and cushions the developing embryo and fetus. The allantois forms from endoderm and mesoderm; its base gives rise to the urinary bladder. The chorion forms from mesoderm and trophoblast; circulation through chorionic vessels provides a "rapid transit system" for blood and nutrients.

24. (1) embryonic disc (an oval sheet of cells, develops at days 9-10 from blastocyst inner cell mass)
(2) blastocyst (a hollow ball of cells, formed after five days of cleavage)
(3) morula (a solid ball of cells, formed during the first five days after fertilization)
(4) zygote (the fertilized ovum, prior to the start of cleavage; cleavage begins immediately after fertilization and ends with the formation of the blastocyst)

25. The trophoblast is the outer layer of cells that surrounds the blastocoele. Its functions include:
    a) eroding a path through the uterine epithelium to merge the blastocyst with the functional zone of the endometrium
    b) absorbing nutrients from uterine cells to support the early stages of embryo

formation
c) creating lacunae through which maternal blood percolates
d) participating in the formation of the placenta
e) secreting placental hormones

26. (a) Dilation stage. This begins with the onset of true labor, as the cervix dilates and the fetus begins to slide down the cervical canal. Late in this stage the amnion usually ruptures.
(b) Expulsion stage. This stage begins as the cervix dilates completely and continues till the fetus has completely emerged from the vagina (delivery).
(c) Placental stage. The uterus gradually contracts, tearing the connections between the endometrium and the placenta and ejecting the placenta.

27. Multiple factors interact to produce and continue labor contractions. Relaxin produced by the placenta softens the pubic symphysis, and the weight of the fetus then deforms the cervical orifice. Deformation of the cervix and the rising estrogen levels promote the release of oxytocin, and the already-stretched muscles become even more excitable.

28. (1) Neonatal period (birth to 1 month). The newborn becomes relatively self-sufficient and begins performing respiration, digestion, and excretion for itself. Heart rates and fluid requirements are higher than those of adults. Neonates have little ability to thermoregulate.
(2) Infancy (1 month to 2 years). Major organ systems (other than those related to reproduction) become fully operational.
(3) Childhood (2 years to puberty). The child continues to grow and there are significant changes in body proportions.

29. Puberty initiates adolescence. Three events interact to promote increased hormone production and sexual maturation at puberty:
(1) the hypothalamus increases its production of GnRH
(2) the anterior pituitary becomes more sensitive to the presence of GnRH, and there is a rapid rise in the circulating levels of FSH and LH
(3) ovarian or testicular cells become more sensitive to FSH and LH. These changes initiate gametogenesis and the production of male or female sex hormones that stimulate the appearance of secondary sexual characteristics and behaviors.

30. "Maturity" is an imprecise term, since the boundary between adolescence and maturity can be difficult to pinpoint. Maturity often refers to the cessation of growth (usually in the late teens or early twenties). Different systems reach maturity at different times; an individual is reproductively mature immediately after puberty, but skeletal maturation continues until the last epiphyseal plates close, sometime after age 20.

31. Senescence refers to the process of aging, which affects all organ systems. Examples include:
a) loss of elasticity in skin
b) declining rate of bone deposition and degenerative changes in joints
c) reduced muscular strength

d) impaired coordination, memory and intellectual function
e) reduced production of and sensitivity to hormones
f) cardiovascular problems
g) reduced immune system function
h) less elasticity in the lungs
i) decreased muscle tone along the digestive tract
j) less muscle tone in urinary system
k) functional impairment of reproductive system.

32. d
33. b
34. d

35. Polyspermy is prevented by the cortical reaction, in which oocyte vesicles release their sperm-inhibiting contents via exocytosis.

36. The hormones produced include human chorionic gonadotropin (hCG). In function hCG resembles LH, for it maintains the integrity of the corpus luteum and promotes the continued secretion of progesterone which keeps the endometrial lining functional. Human placental lactogen (hPL) and placental prolactin - hPL helps prepare the mammary glands for milk production. The conversion from the resting state of the mammary glands to active status requires the presence of hPL and placental prolactin, and several maternal hormones. Relaxin is a peptide hormone that increases the flexibility of the pubic symphysis, causes dilation of the cervix, and suppresses the release of oxytocin by the hypothalamus, delaying the onset of labor contractions.

37. The respiratory rate and tidal volume increase. This allows the lungs to obtain the extra oxygen and remove the excess carbon dioxide generated by the fetus. Maternal blood volume increases. This compensates for blood that will be lost during delivery. Requirements for nutrients and vitamins climb 10-30 %. This reflects the fact that part of the mother's nutrients go to nourish the fetus. d) Glomerular filtration rate increases by about 50 %. This corresponds to the increased blood volume and accelerates the excretion of metabolic wastes generated by the fetus.

38. By delivery the uterus has quadrupled in length and grown to almost 20 times its original weight. This leads to tremendous stretching in the myometrium, which is associated with an increase in smooth muscle contractions. Progesterone released by the placenta inhibits the uterine smooth muscle to prevent more-violent contractions. The calming action of progesterone is opposed by estrogens, oxytocin, and prostaglandins; later in pregnancy the production of estrogens and prostaglandins increases.

39. Progesterone released by the placenta has an inhibitory effect on the uterine smooth muscle.

40. Positive feedback mechanisms ensure that labor contractions continue until parturition is complete.

41. The amnion generally ruptures late in the dilation stage of labor.

42. Adjustments that a neonate must make include filling the lungs (which are collapsed and filled with fluid at birth) with air. The expansion of the lungs changes the pattern of cardiovascular circulation due to changes in blood pressure and flow rates. After birth the mixture of debris which has collected in the fetal digestive system is excreted, and the neonate begins to obtain nourishment from a new source: the mother's mammary glands. Neonatal fluid requirements are high, since the infant cannot concentrate its urine significantly. The infant also has little ability to thermoregulate at first, although as it grows its insulating adipose tissue increases and its metabolic rate also rises.

43. a) Monozygotic twins ("identical") result from either the separation of the blastomeres early in cleavage, or by splitting of the inner cell mass prior to gastrulation. The genetic makeup of the pair will be almost identical, since both formed from the same gamete. Dizygotic twins result from two separate oocytes that were subsequently fertilized. b) Genotype refers to the genes of the individual. Phenotype refers to the physical and physiological characteristics of the individual. The genotype is a primary determinant of the phenotype, although other factors (injury, disease, environment) can also play a role. c) If both chromosomes of a homologous pair carry the same allele of a particular gene, the individual is homozygous for that trait. If the two chromosomes carry different alleles for that gene, the individual is heterozygous for that trait. d) In simple inheritance, the phenotypes are determined by interactions between a single pair of alleles. Polygenic inheritance involves interactions between multiple genes.

44. a) dominant b) recessive c) X-linked trait d) autosomal trait

45. The trait of red-green color blindness is carried on the X chromosome. Men are thus more likely to inherit it because they have only one X chromosome, so whatever that chromosome carries will determine whether he is color-blind or has normal vision. Since women have two X chromosomes, they will be color-blind only if they are homozygous-recessive. Red-green colorblindness is an example of X-linked inheritance.

46. Genetic recombination occurs at synapsis during meiosis, and results in increased variability in traits carried by different gametes and therefore in offspring. The process involves breaking off and switching pieces of homologous chromosomes.

47. The Human Genome Project is attempting to determine the normal genetic composition of a "typical" human being. The project will help to identify the genes responsible for inherited disorders and localize the specific chromosomes involved.

Level 3: Critical Thinking/Clinical Application

48. None of the couple's daughters will be hemophiliacs, since each will receive a normal allele from their father. There is a 50% chance that a son will be hemophiliac since there is a 50:50 chance of receiving either the mother's normal allele or the recessive allele.

49. Joan's physician refused her request because excess calcium could cause tetanic contractions of the smooth muscle of the uterus. This would cut off the blood supply to the placenta, and the fetus would be deprived of oxygen.

50. During nursing, the mechanical stimulus of suckling triggers a neural reflex that leads to the release of the hormone oxytocin from the posterior pituitary. Oxytocin enters the bloodstream and stimulates smooth muscle in the ducts of the mammary glands to contract and move milk into the lactiferous sinuses, a process known as "milk letdown" or milk ejection. Since oxytocin receptors are also found on smooth muscle cells of the uterus, the rise in oxytocin sometimes leads to uterine contractions as well, producing a feeling similar to menstrual cramping.

51. The fact that the adults are larger is precisely why their rates are lower. Heat is lost across the skin. In infants, the surface area to volume ratio is high. This means that infants lose heat very quickly. In order to maintain a constant body temperature in the face of the heat loss, cellular metabolism must be high. Cellular metabolism requires oxygen, thus increased metabolism demands an increased respiratory rate. There must also be an increase in cardiac output to move the blood from the lungs to the tissues. Since the range of contraction in the neonate heart is limited, the greatest increase in cardiac output is achieved by increased heart rate.

52. The active ingredient of aspirin blocks enzymes necessary for the production of prostaglandins. Since prostaglandins play an important role in uterine contractions during parturition, blocking their synthesis would interfere with normal labor. Prostaglandins are also involved in coagulation. Taking aspirin could increase the time it would take for blood to clot following delivery, leading to excess blood loss and the possible need for a transfusion.

53. The baby's condition is almost certainly not the result of a virus contracted during the third trimester. The development of organ systems occurs during the first trimester. By the end of the second trimester almost all of the organ systems are fully formed. During the third trimester, the fetus undergoes tremendous growth, but very little new organ formation.

❑ Media Lab Instructor Notes

Web addresses often change. To avoid dead links, we are listing the keywords in parentheses next the to Web Explorations. Simply go to the Companion Website (http://www.prenhall.com/martini), select the Fifth Edition of Fundamentals of Anatomy and Physiology and search using the key word to locate the current address.

Animations (Website)

- Figure 29-1—Animation in play / next format. Fertilization; suitable for lecture demonstration of fertilization or self-study.
- Figure 29-3—Animation in play / next format. Stages in the implantation process; suitable for lecture discussion of implantation or self-study.
- Figure 29-18—Animation in play / pause format. X-linked inheritance; suitable for lecture discussion of Punnet squares and Sex-linked inheritance or self-study after presentation.

Web Explorations (Overview)
Web Exploration 1 (**TIME LINE**)

- *Goal*—review, expand knowledge
- *Description of page*—University of Pennsylvania Med School training tool for development
- *Expectations of student behavior*—study time line, click on image labels, move through sequence
- *Instructor's role*—present development; assist in navigating site, correct thought processes as time line created
- *Special notes or further uses of exploration*—no external links; first page allows navigation to any other stage in series

Web Exploration 2 (**HUMAN GENOME PROJECT**)

- *Goal*—critical thinking, application of information
- *Description of page*—Human Genome Project Information page—links to internal pages
- *Expectations of student behavior*—read information, discuss implications
- *Instructor's role*—explain DNA and genes, lead discussion, keep students on track due to links
- *Special notes or further uses of exploration*—many links to other aspects of project, good page for personal research or student project information

Additional Web Explorations

Should the two explorations found in the text not answer your needs, a third exploration is provided below. Your students do not have direct access to this exploration. You must provide them the address and information in the following paragraph.

Web Exploration 3

Estimated time for completion = 10 minutes

One of the most exciting procedures a woman experiences during a pregnancy is the ultrasound. Using sound waves bounced against the soft tissues of the uterus, an image of the developing embryo or fetus is created. It is the mother's first view of her baby, albeit a difficult view to interpret. To gain an understanding of **ULTRASOUND** images, go to the web address (http://www.ob-ultrasound.net/). Read the short prose and click on the internal links. Prepare a short outline of the use of ultrasound in pregnancy, including what can be detected, and when these images are usually taken.

Web Address http://www.ob-ultrasound.net/

Web Exploration 3 (**ULTRASOUND**)

- *Goal*—knowledge application, concept review
- *Description of page*—Obstetric Ultrasound information created by Dr. Woo and Amazon.com
- *Expectations of student behavior*—read, click on numerous links, create understanding through outline
- *Instructor's role*—explain ultrasound, assist in interpreting links (images versus outside pages)
- *Special notes or further uses of exploration*—tremendous amount of information, from history to new research findings to ultrasound images, useful as resource for student projects

Topic Outline				A/V Resources				
Objectives	**Chapter 29** **Development and Inheritance** (page 1 of 3)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	I. Introduction		5a					
1	**II. An Overview of Topics in Development**							
3b	**III. Fertilization**	29-1a			●	●		
	A. The Oocyte at Ovulation	29-1b	3a	●	●	●		
3c	B. Oocyte Activation	29-1b	3b	●	●	●		
	IV. An Overview of Prenatal Development							
	V. The First Trimester		6a					
	A. Cleavage and Blastocyst Formation	29-2		●	●		●	
	B. Implantation	29-3	5b	●	●	●	●	●
	1. Formation of the Amniotic Cavity	29-3,4		●	●		●	
3d	2. Gastrulation and Germ Layer Formation	29-4	5c	●	●		●	
	3. The Formation of Extraembryonic Membranes	29-4,5,6		●	●			
3e	C. Placentation	29-5cde, 6a		●	●			●
	1. Placental Circulation	29-6	6b	●	●			●

Topic Outline				A/V Resources				
Objectives	**Chapter 29** **Development and Inheritance** (page 2 of 3)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	2. The Endocrine Placenta							
	D. Embryogenesis	29-5bc,7		●	●			
	VI. The Second and Third Trimesters	29-7d,9,10		●	●			
3f	A. Pregnancy and Maternal Systems	18-17b	4a	●	●			
3g	B. Structural and Functional Changes in the Uterus	29-11		●	●			
4	**VII. Labor and Delivery**							
	A. Stages of Labor	29-12		●	●			
	1. The Dilation Stage	29-12a		●	●			
	2. The Expulsion Stage	29-12b	3c	●	●			
	3. The Placental Stage	29-12c		●	●			
	B. Premature Labor							
	C. Multiple Births							
5a	**VIII. Postnatal Development**							
	A. The Neonatal Period, Infancy, and Childhood							

TOPIC OUTLINE				A/V RESOURCES				
Objectives	**Chapter 29** **Development and Inheritance** (page 3 of 3)	Figures	Strategies	Transparency	Still-CD	Anim-CD	Video Tutor	Quiz Art
	1. The Neonatal Period	29-13		●	●			
	2. Infancy and Childhood	29-14			●			
	B. Adolescence and Maturity							
	C. Senescence							
2	**IX. Genetics, Development, and Inheritance**							
	A. Genes and Chromosomes	29-15	3d		●			
	1. Autosomal Chromosomes	29-16,17	2a		●			
	2. Sex Chromosomes	29-18			●	●		
	B. The Human Genome Project	29-15,19		●	●			

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